

WIP: Engineering and Learning affordances for multilingual learners in elementary classrooms

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Abstract—This is an innovative practice Work in Progress paper regarding teacher development around engineering and language. It is known that sustained Professional Development (PD) programs result in better uptake and implementation of best practices with US public school teachers. Furthermore, there is an ever-increasing number of multilingual learners in US public school classrooms, necessitating new practices by teachers and support structures to better assist these students' learning. Engineering provides a powerful location for shared growth and learning in the curriculum. Further, this area provides an avenue for teachers to utilize more inclusive language ideologies, such as translanguaging. Language ideologies are the beliefs, values, and attitudes which surround and influence the structure and usage of language. Translanguaging is a specific form of an inclusive language ideology geared toward multilingual learners which empowers them to leverage their full language repertoires (in whatever language or dialect), rather than exclusively the language of instruction. We have initiated a sustained professional development project with elementary school teachers in US Public schools who have multilingual learners in their classrooms. We invited them to a summer Professional Learning Experience and several half-day workshops where we worked with the teachers to learn about engineering, translanguaging, and how to apply these topics within their classrooms. We then went into the classrooms and recorded their execution of engineering unit(s). This paper presents the case study of a third-grade teacher, Emma, who has been implementing engineering projects with her students. We examine her changing positions related to engineering and linguistic usage in these projects and her classroom.

Keywords—

I. INTRODUCTION

This is an innovative practice Work in Progress paper regarding teacher development around engineering and language. 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 native English speakers due to mistaken beliefs that children need to be fully proficient in English before they can participate in STEM activities and learning. Therefore, emergent bilingual students are often placed in tracks with less rigorous content, low expectations, and fewer opportunities to participate in math, science, or engineering lessons. This leads to greater inequities between emergent and multilingual students and their monolingual English peers. In elementary schools STEM opportunities may be further impeded because many elementary teachers express discomfort and a lack of experience and preparation to teach science and engineering and in providing instruction for emergent bilingual and multilingual learners.

The NSF-funded project described in this paper seeks to develop a model of sustained professional development for elementary teachers to address the dual challenges of a lack of preparation to teach engineering and in teaching emergent bilingual and multilingual students. The project is in year one of three award years and focuses on developing understandings of how teachers of multilingual students learn to teach engineering while also reconsidering language ideologies particularly through the lens of translanguaging pedagogies. This paper presents a work-in-progress case study of one teacher.

II. BACKGROUND

Despite deficit-based dispositions that sometimes lead educators to exclude emergent bilinguals from STEM activities, research has demonstrated that engineering is a promising discipline for adopting an

asset-based pedagogy for multilingual students [2], [3], [4]. Additionally, according to the Next Generation Science Standards [5], “engineering has the potential to be inclusive of students who have traditionally been marginalized in science classrooms” because they can “engage in science in socially relevant and transformative ways” as they “solve problems through engineering” (Appendix D, pp. 4-5). However, engineering is not typically included in teacher education programs [6], [7], [8], and may be intimidating for elementary teachers who often have little science background.

Undergirding teachers' instructional practices for multilingual students are teachers' language ideologies. Language ideologies [9] such as beliefs about what is standard linguistic structure or what is culturally appropriate govern much of classroom life and many instructional decisions made by teachers. For example, ideological positions 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—even if children must use languages other than English in the classroom (an asset-based view).

Translanguaging is a pedagogical and theoretical construct [10] that aligns with the latter asset-based view and proposes that teachers should build a classroom environment that facilitates and encourages use of all language repertoires. Translanguaging is thus both a viewpoint and set of practices embraced by teachers to invite students full linguistic repertoires into usage in the classroom. Research in multilingual settings has shown that translanguaging can be an integral component of fostering a multilingual ecology during engineering lessons [3]. As Esquinca et al note, translanguaging includes not only spoken language, but multiple modes of communication (i.e., multimodality) that carry meaning [11]. 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 [12], [13].

Given that teachers are often unfamiliar or even uncomfortable with teaching engineering and working with multilingual learners, this project seeks to address these two challenges through sustained professional development. A number of models exist in the Engineering Education community to facilitate professional learning experiences for K12 teacher professional development within the US. These include INSPIRE cohorts [14], [15], Novel Engineering through children's books [7], [8], [16], and the tiered model EDSTOP [6]. While some of these have the dissemination of materials and available support staff for questions, rarely do they have an extended duration. Furthermore, these professional learning experiences (PLE) are typically exclusively focused on content, predominantly or exclusively in English, and designed as interventions. PLE should guide teachers through extended engagement with engineering, the engineering design process, and any concepts desired to train them how to teach. This is for their enhanced familiarity and confidence or comfort with the material, as well as guiding them through the taking up of different roles which is required in this process. During the learning of engineering, classroom teachers have to shift between learner, activity facilitator, evaluator, classroom administrator, and teacher, all in a content or subject area they are highly unfamiliar with.

Additionally, teacher preparation programs, particularly for elementary teachers rarely focus on engineering skills, concepts, and pedagogy. Furthermore, despite significant amounts of research showing that sustained PD are more effective and result in longer, more effective uptake of methods, many PD programs are short, single instance workshops. These single instance offerings rarely address the core issue identified by K12 classroom teachers in the US regarding their ability to implement engineering. Teachers report a perceived lack of preparation or training, lack of background knowledge, insufficient time preparing lessons or using materials, and lack of confidence [17], [18]. PLEs should be “of longer duration and time span” as this “is more likely to contain new kinds of learning opportunities ([19] pg 929)” and incorporate time for instructional planning. In addition, effective formats for PLE offer expert support, and focus on content (both technical and pedagogical) for classroom teachers [20]. Research indicates that long-term engagement through community building, collaboration with teacher participants in participatory research, and sustained engagement with content is most effective in mitigating the barriers to engineering identified by classroom teachers and leading to long-term implementation of practices.

III. METHODS

This study is part of a larger National Science Foundation project working with teachers of multilingual students in upper elementary classrooms. The project utilizes a participatory design-based implementation research methodology (DBIR), meaning our study design is iterative and responsive as we collaborate with our partner school districts.

This study follows a single case study of one teacher from year one of our project. We chose Emma as a case due to her strong self-awareness and insightful reflections. Even at this nascent stage of the project and early phase of her engineering education journey, Emma demonstrates significant growth. This provides an opportunity to examine preliminary impacts and outcomes at this developmental phase.

Professional Learning Experience format

The PLE follows a sustained professional development model that includes a three-day summer experience and four half-day experiences throughout the school year. The PLE goals are to prepare teachers to teach engineering lessons to emergent bilingual and multilingual students in upper elementary school classrooms with the goal of teaching one or more engineering units during the school year. The PLE began with the initial three-day professional development introducing teachers to engineering and the engineering design process as well as the concepts of language ideologies and translanguaging. Engineering lessons included participating in engineering design activities (e.g., designing a snowball keeper and a device to prevent lakeshore flooding), discussing the steps of the engineering design process, and reading practitioner articles about emergent bilingual and multilingual students.

Teachers were introduced to the concepts of language ideologies and translanguaging through videos and reading published resources (e.g., [21]). Through reflection and discussion, they were asked to discuss ways they currently attempt to include all of each students’ linguistic resources as well as new languaging practices they want to include. Teachers also discussed how to use translanguaging practices during engineering activities.

During the school year, half-day PLE experiences included engaging in additional engineering design problems, discussing the testing and iteration steps of the engineering process, and discussing articles on translanguaging. Teachers planned their engineering lessons with input from researchers. Lessons included engineering and language objectives.

Data collection and analysis

The research team collects data during all study events including summer and school year teacher professional development classroom teaching, pre-interviews, and post-teaching interviews. Data are collected using audio, video, field notes, photographs, and memos. The

primary focus of this paper is the interview data. Emma was interviewed before the summer PLE and then twice more after teaching engineering lessons. Each of the second and third authors conducted one of these interviews shortly after Emma completed the first engineering unit she had developed and delivered with her classroom. During this interview, she discussed delivering another engineering unit during the early spring semester. This unit was observed by all three authors. After this unit was concluded, the first author interviewed Emma again. All interviews were semi-structured and explored the design intentions, translanguaging practices, execution and facilitation of engineering, and considerations of student learning. Each interview was transcribed using an online service and checked for accuracy.

These interviews were analyzed using our primary research questions for this entire project. Namely, we looked at how Emma had shifted in her:

- A. Language ideologies
- B. Use, understanding, or application of Translanguaging
- C. Understanding and implementation of Engineering

The first author led initial coding to determine Emma’s positions and changes or development from previous positions. Analysis was carried out through rounds of iterative coding, examining for instances, utterances, and discursive patterns around topics related to how Emma viewed engineering or her positions reflecting translanguaging and language ideologies. Using both inductive and deductive approaches, we examined Emma’s responses to interview questions.

IV. RESULTS

Emma’s initial position on language ideologies, engineering, and translanguaging was determined through analysis of her pre-PLE interview to ascertain her existing knowledge and positions before engaging in the PLE. Emma has some exposure and experience with engineering, having done a STREAM project in a previous classroom. However, due to an absence of support, resources, training, and a lack of formal schooling on the topic, she does not identify as a teacher of engineering, as “it was never a part of my training and schooling, I’ve had no specialization or preparation with it.” She also explicitly contrasts her expertise having a “background in literacy” with the expertise of a STEM teacher who would be more prepared to teach engineering. Secure in her literacy teacher identity, Emma notes that she has a significant awareness of research in phonics, phonetics, and the precise mouth/facial motions required for sounds and how this relates to learning languages, particularly through the lens of reading and writing. In her pre-interview, Emma expresses a very inclusive and student-centric language ideology. She refers to students as “friends,” makes a point to center their learning through encouraging students to engage in whatever language is most comfortable for them since things like “reading comprehension skills are universal beyond language” and thus can serve as “a nice on-ramp to access grade level content.” Emma has a professed appreciation of languages, evident through her description of students as “the experts of their own culture. I like to capitalize on that” particularly when they are invited to bring elements of their culture into the school for multicultural day. Emma reflects on her limited competence with a second language, expresses an admiration for people who are multilingual, and positions the knowledge or mastery of multiple languages as a significant asset, stating that “I think that people who are bilingual are the coolest people. And I always want to learn things.” She reinforces this point when she positions herself as a learner as she “always encourage the kids to teach me something like, How do I say hello to you in your language? Then I try it and then they laugh at me because I get it wrong. But I always try to get little pieces of things from them.” With this utterance, Emma is positioning herself as a learner, and the students as the more expert individual instructing her on their language.

Emma also states that a major goal of her classroom is a desire for “students to feel comfortable with risks and vocabulary authentic experiences” and as such she invites students to be collaborators in her classroom. She also says she wants to help “teach them what is school

in America” in order to “bridge that cultural gap” since her major stance is that “language is embedded in relationship and culture.”

Emma has very strong ideological alignment with translanguaging, utilizing inclusive strategies in her classroom. These have been pervasive in her practice even predating the PD experience, and as such there is significant influence already present in her teacher persona. She discusses her previous classes of students, how they were engaged in the classroom setting and she encouraged them to work together, and how she often “encourages students to use their home language” when starting a textual analysis, writing task, or reading exercise. Emma asserts that “reading comprehension skills are universal beyond language” and that when students are encouraged to use their home language “it’s a nice on-ramp to access grade level content, especially with those higher level comprehension skills.” This asset-based view is further exemplified by her description of the school’s “multicultural day [when students are] coming in, showing different items, artifacts from their culture,... they’re the experts of their own culture. I like to capitalize on that.” These are all existing ideas and views Emma came into the program with, enabling her to rapidly acclimate to translanguaging and an inclusive language ideology.

A. Emma’s shifting view of Language Ideologies

Emma has shifted her view of language ideologies through the course of the year and delivered several engineering units. She has shown an increasing awareness of the nuanced development of ideas relating to the modality of language. She notes how many of her students work together “by demonstrations and gesturing” and “finding different ways to communicate.”

This includes an increasing consideration of non-verbal communication methods. She notes how one of her emergent bilingual students engaged in this process and how it “was very interesting for him because he could communicate in both ways, but also things like communicating through drawings and pictures and drawing arrows and labels. The kids found many different ways to communicate that was not just verbal speech, especially for those kids and they were very successful.” Here Emma is specifically referring to verbal, nonverbal, and symbolic communication that her student is able to utilize to engage with his peers, the majority of whom English is the only shared language. This shows more openness and awareness of the importance of these types of communication. She also planned for this in her engineering lessons. For example, she included a four-square planner that encouraged students to draw their ideas. Instructions were provided in Spanish and English. Using the language of their choice, some students labeled or wrote instructions on their illustrations.

Emma at one point mentions how the “materials of [an] engineering project ARE the vocabulary for the project.” (emphasis added). Within this she is showing an emergent consideration of the various ways language can manifest outside of the spoken language of instruction, which aligns well with her original highly inclusive and welcoming language ideology. Engineering is serving as a vehicle for this emergent awareness. Emma is considering materials as a different set of vocabulary words and considering the value of gestures and drawings as a form of communication, instead of merely a supplementary element of language. This is another example of her expanding viewpoint of language and its multiple methods of enactment by students such as nonverbal, symbolic, or gestures. Within our PLE, a discussion emerged during one of the engineering activities about how engineers communicate via drawings, ideas and models, and hand gestures. This idea has developed with Emma and shifted her lens on language. She already viewed multiple languages as equally valid within the classroom, but the combination of this activity, the engineering design experience within the PLE, and the reflection on her students engagement with engineering units within her classroom has further expanded her lens to encompass multiple modes of communication beyond the verbal as relevant and impactful.

B. Emma’s shifting usage of Translanguaging

Emma was not aware of the term translanguaging before participating in the PLE, she already infused many translanguaging

techniques and attitudes in her teaching. The PLE allowed for an expansion of knowledge, a developing awareness of translanguaging practices and the ability to name and describe some of what she is doing already. Emma mentions how she intentionally neglected any major implementation of new translanguaging techniques with the first engineering project. She reflects that she “wasn’t as encouraging of them to use their home language. I was really trying to get the process first so I could be confident in that.” Emma is describing the process of teaching engineering, of executing an engineering design project, and specifically guiding or facilitating her students through a design cycle as the new innovation. However, there was still a level of actions and strategies which Emma used that were evident of translanguaging. “There’s a bunch of students who - they all speak different languages - but [the engineering project] allowed them the visuals.” Emma here is describing how students were able to mutually engage with the materials, the diagrams or symbolic communication, and the visual understandings of the project. Emma notes how the expansion of language into multiple modalities benefits all her students. She especially discusses how she also had some students who “speak with a heavy accent... they were really able to reference drawings and communicate more articulately through visuals.” Emma, during her second engineering project, integrated translanguaging strategies in small ways, though she self-acknowledged that this was due to necessity. “I have those three students who are emerging, and 6 more students with broken English... they used a lot of strategies like gesturing, demonstrating, materials, so we were able to access the engineering.” Emma is noting the power of engineering for her students across all demographics, irrespective of their English proficiency. Emma further mentions how she invited a bilingual student to serve as her assistant in translating for three other students who all shared the same home language (Spanish, in this case), putting this student in “kind of a leadership opportunity. Even though it was honestly a survival mechanism for me.” Emma is leveraging her classroom resources, in the form of student expertise and abilities, to facilitate student learning. Despite her characterization of this empowerment of a peer as a survival mechanism, this still shows a significant amount of autonomy and trust given to the translating student. Emma later asserts that “my goal for [these emergent ENL students] in my classroom is to have them doing as close to what everyone else is doing as possible.” She wants the students to all be engaged and learning, and recognizes that the language of instruction is not equally comfortable or accessible for her students. As such, she is utilizing additional strategies and multimodal methods of delivery to allow students additional inroads to grasp the materials.

C. Emma’s shifting understanding of Engineering

The largest shift in Emma’s teaching practices is in regard to engineering. Emma showed an increasing level of confidence, comfort, and familiarity with engineering. Her first engineering project with her class was to “test it out, get confident with the process and what to look for.” Contrastingly, Emma’s second engineering project was to “try again, be more flexible and creative and more responsive.” Emma explicitly says in regards to her multiple practices of engineering “that’s why I wanted to do [first engineering project] now, so that there are some things I could learn from it.” Within this, Emma recognizes and engages with the fact that engineering and the teaching thereof are highly experiential; one learns how to facilitate the teaching of engineering by enacting the teaching. Consequently, Emma chose to practice her engineering teaching several times earlier in the school year, prior to the originally planned observation and data collection which had been mentioned during the summer PLE.

Emma intentionally and explicitly replicates a number of educational models and formats utilized in the PLE. “I wanted students to experience the same activities and power I did,” as “all of you over the summer, [did a great job] of making engineering extremely accessible to a teacher like me who really just comes from a literacy background and I don’t have a lot of engineering [knowledge]. I learned so much

and I was able to implement a lot of the things that we talked about.” Emma here positions herself as very novice to the topic of engineering, contrasts again her literacy background and focus, and then praises the approachability of the topic which was conveyed by the research team. This is very indicative of Emma as a teacher; excited and willing to show the students the power of engineering by explaining her experiences as a novice learner. She then expresses how she wanted to implement many of the lessons or ideas with her students that she had just learned during the professional development.

Emma further mentions how she has made “some additions in the classroom that I’ve made to support the engineering process because it’s really cool. I’m a huge fan.” She especially highlights several places that she has added classroom decor and infographics about engineering. These include a “what is an engineer” class constructed poster, a display of the designs from their first engineering project, and the engineering design cycle (adapted by Emma into a more child-friendly format) above one whiteboard, complete with a red arrow to indicate to the students at which stage they are focusing during each day of the engineering project units.

“I told them about my experience over the summer, I created documents just like how we did over the summer, I showed them the materials.” Emma refers to the series of guiding documents provided to the teachers at the PLE, to help them organize their ideas through the design, ideate, and problem research or framing stage.

Emma also showed increasing awareness of the value of engineering as “equalizing” particularly for students “regardless of language, IEP, gifted/talented, ENL, etc.” At one point she even reflects that “[it’s] like we had said over the summer, [engineering is] equal access because there’s no background knowledge really needed. It’s all just logic and reasoning. And so it gave every student the chance to think.” This is a point she comes back to often, reflecting on her experiences teaching engineering in her classrooms and comparing it to her experience in our summer PLE. As she puts it, “everything we talked about over the summer happened.”

Emma further notes a key feature that drew her to engineering was “you do not need to speak the same language as other people. And that kids are so interesting and creative in the way that they communicate.” Emma reiterates her positioning of the students as equal participants in the classroom, the power of non-verbal and symbolic communication in engineering, and how she drew on the PLE experiences to design her own units.

Emma summarizes her reflection of her two engineering units, as “the first time around it was just kind of see how this plays out, how does each step work and allocating time for each step.” Then the second project was much more hands off, allowing the students to engage within and follow the engineering process in designing a solution to the problem they had co-constructed.

We see a direct and clearly visible incorporation of topics discussed in the PLE incorporated into Emma’s engineering units. For a specific example, during our January PLE we focused on failure and the iterative testing process. Her second project, in early February, had significant amounts of time allocated to the testing, refining, and improving of prototypes for students. Emma reflected on this second project that “this time around, I really wanted to focus on problem scoping and the testing and improving cycle because we didn’t get a chance to really do that so much the first time around. We had done that [PLE] at {university} where {author} actually modeled for us that problem scoping with an article.” She further states that “[engineering] was so accessible to the point where I thought, well, I want to try this right away. I want to get started.” Emma thus implements many of the activities, attitudes, and modeled teaching practices from the PLE into her execution of engineering units. She continues this implementation and incorporation through the school-year, implementing elements such as problem success criteria identification and planning for failure,

which is viewed as a learning opportunity within engineering and is often expected, as these items were explicitly discussed and modeled in the mid-year PLE.

V. DISCUSSION

We see significant differences in Emma’s perspectives on the research topics over the course of these lessons. Emma goes from being a novice at engineering, enthusiastic and excited, to being extremely confident. She is comfortable trusting students to explore on their own. She reflects, “[M]y role in the engineering process is literally just to teach them the process and then let them go.” Emma also directly integrates a number of translanguaging practices and methods into her classroom, namely her multilingual vocabulary wall and through the use of home language materials for ENL students. She encourages these students to work with their home languages during the engineering group work, and translates their work via software when she needs to discuss their ideas with them. Emma has shifted her already inclusive language ideologies to an even more expanded view. She has incorporated more of an appreciation for multimodal communication, the use of gestures or symbols, and even construction materials as a way of facilitating learning or discussions. She underscores the view that activities, assignments, and lessons are entirely dedicated to student learning. The format, language spoken, and outcome of that lesson are much more secondary to the actual student’s learning process. The tactics Emma used, the motivation behind them, and the significant impact those had upon her students serves as an excellent example of the research project’s goals in action. Accordingly these can serve as a set of examples for other members of our study and future PLE participants.

VI. IMPLICATIONS AND CONCLUSIONS

The case of Emma provides an excellent example case of one teacher doing these works well, of embracing the challenges presented by new conceptual areas and linguistic ideologies. As this is a single case study, and as such makes no generalizable claims, future work from our study and others can help affirm these findings. Despite this, Emma is an example of a teacher fully embracing these topics and engaging in new methods to facilitate student learning and access, and serves as an exemplary model for others to draw strategies, tactics, and ideas from.

From this case study we see our hypothesis of the equalizing power of engineering playing out. Emma focuses on the opportunities for learning embedded in engineering rather than on correct English writing or speaking. She leans into the potential of all students to interact and engage with engineering, irrespective of student’s previous academic performance or language proficiency in English. Emma is becoming significantly more comfortable, confident, and capable as an educator of engineering. She makes an explicit effort challenge her own learning by teaching several units with decreasing levels of structure and formality, treating the engineering design process more as a guideline process than a strict sequence of steps. Emma also directly incorporates many of the practices modeled by researchers into her engineering lessons. Thus, we anticipate our increasing community of teachers for our PLE to be similarly successful in building their repertoire of engineering skills. As a core element of our project is the co-construction of the community and co-construction of knowledge, we envision Emma as a possible teacher leader, educating and mentoring new members of the PLE community. While still in the preliminary phase, Emma’s case suggests that supportive PLE can help teachers (1) shift language ideologies and (2) grow in understandings of engineering and translanguaging in ways that directly impact the classroom ecology for multilingual learners.

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