A Learning Engineering Approach to Transforming Teacher Practice Through Co-Designing Science Curricular for Multilingual Learners

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This practitioner-focused paper describes the application of a learning engineering process to co-design a science unit on chemical and physical changes for 6th grade classrooms. In partnership with a group of science teachers and specialist from highly diverse urban schools, researchers facilitated a two-week summer institute, co-creating a unit anchored in a culturally relevant phenomenon. Drawing on the principles of collaborative design as professional development (Severance, 2022; Voogt et al., 2015), the study investigates how the co-design process can be structured and how it impacts teachers' perceived ability to support science learning of diverse learners. Data from co-design artifacts, classroom observations, and focus group teacher interviews revealed that the process fostered significant teacher agency and provided a powerful context for professional learning. The findings offer a replicable model for using learning engineering to create culturally and linguistically relevant science instruction.

Introduction

The effective integration of Science and Engineering Practices (SEPs) into culturally and linguistically diverse middle school classrooms remains a significant challenge (Lee, 2019). Teachers often lack the resources and professional learning experiences paramount to step beyond scripted curricula and design learning experiences that are both rigorous and receptive to students' cultural and linguistic assets (Garcia & Wei, 2014). Situated in a research practice partnership between university researchers and a grades 6-8 science team in a large urban district, this study applies a nested learning engineering methodology (Craig et al., 2024; Kessler & Totino, 2023) to the teacher-researcher collaborative co-design of science curricula. While the overarching project follows a 4-years engineering cycle (Challenge, Investigation, Creation, Implementation), the annual summer co-design institute represents a focused, iterative micro-loop within the Creation phase. This nested cycle comprises its own investigation (needs assessment), creation (unit adaptation), and user testing (classroom implementation), which allows for responsive, year-to-year refinement of the curriculum to better serve all learners including multilingual learners (MLs). This approach aligns with several high-leverage opportunities for learning engineering identified by Baker et al. (2022), specifically those steered toward supporting diversity, equity, domain-based research, and the integration of human and systemic supports in education. This approach, defined as a human-centered and iterative way to design learning environments, is most effective when it focuses on co-designing with teachers (Edelson, 2002).

Unlike mere collaboration, curricular co-design is a structured process where teachers and researchers jointly define problems and develop solutions, creating a context for profound professional development and curriculum innovation (Voogt et al., 2015). This process fosters teacher agency, positioning educators as authors of curriculum rather than bald implementers (Severance, 2022). Furthermore, informed by asset-oriented pedagogies and inquiry-based science learning, the current study aims to explore how co-design process can be organized and structured to facilitate co-creating expanded science learning opportunities for all learners including MLs.

This study is guided by the following research questions:

1. How can a learning engineering process be applied to co-design a culturally and linguistically relevant science unit for diverse 6th grade classrooms?
2. How do teachers perceive the co-design process and its effect on their ability to support science learning of diverse learners?

Methods

This study involved four 6th grade science teachers and one specialist from three intermediate schools in one large urban district in Southwest Texas. The district serves a highly diverse student population with 61% of multilingual learners. It is part of a larger federally funded project aiming to use a team-based model to support middle school science teachers to adapt existing science curricular that leverage the communicative practice and strengths of diverse learners. The classrooms included students speaking 5-6 different home languages (other than English) with a wide range of English proficiency. This context made the focus on cultural and linguistic relevance critical. The co-design team, including five teachers, one specialist, and three researchers were engaged in a structured, recurring cycle of Investigate, Create, and Implement across one full academic year. This cycle was embedded within the larger project's Creation phase and was operationalized through a two-week summer institute and monthly Saturday professional development sessions to learn and apply the guiding concepts (contextualized science inquiry, multilingual and multimodal resources, and dialogical science discourse) into the curriculum co-design process through co-design cycles: explore, adapt/design, enact, reflect and modify.

Learning engineering procedure:
We utilized an iterative learning engineering cycle consisting of the key phases:

1. Co-design phase (Summer 2025): A two-week summer institute session laid the conceptual foundation for co-design work. Teachers explored the guiding concepts through hands-on activities, model lessons, collaborative work, and reflections. Then each co-design team selected a unit to adapt for fall implementation. Researchers acted as co-design supporters, facilitating teachers through the process of redesigning an existing unit on chemical and physical change. A key negotiation was connecting the unit in the culturally relevant phenomenon of food (e.g., Texas BBQ) and cooking, which teachers identified as a high-interest topic that could connect to their students' lived experiences.
2. Implementation phase and data collection(Fall 2025): The co-designed unit was implemented by all teachers in their diverse classroom settings. To closely monitor lesson implementation and collect student assessment data, researchers visited each teacher and video recorded the entire 5 lesson unit. This observational data, which included video recordings and structured field notes, along with student artifacts, was specifically focused on capturing student engagement and science sense-making practices. Complementing these observations, co-design meeting minutes, and the iterative lesson plans were collected to document the collaborative process. To capture teacher perspectives, we conducted post-unit group debriefing and individual interviews, focusing on their co-design experience, subsequent shifts in instructional practice, and views on student learning outcomes.

Results

The design and implementation of the Physical and Chemical Change unit for 6th-grade students followed a structured Learning Engineering (LE) process, characterized by iterative, data-informed cycles of design, enactment, and refinement. Our unit's development can be mapped onto two primary phases: Phase 1 - Summer Co-Design (Challenge & Creation) and Phase 2 - Implementation (Implement & Investigate), with embedded micro-cycles that allowed for continuous feedback and adjustment.

Phase 1: Summer Co-Design - Challenge and Creation through Collaborative Backward Design

The co-design process started during intensive summer meetings with full team attendance, embodying the Challenge and Creation phases of the Learning Engineering cycle. The team first identified the core instructional problem: how to teach TEKS 6.6E (evidence of chemical change) in a way that was accessible, engaging, and culturally sustaining for a diverse student population. Informed by LE principles that emphasize contextualized, authentic problems (Baker et al., 2022), the team selected BBQ as the anchoring phenomenon. This choice emerged from discussions about student interests, cultural relevance, and the potential to illustrate both physical and chemical changes in a familiar, real-world context.

Using a backward design approach, the team started with the TEKS standard and mapped out a 5-day learning progression using the 5E instructional model. Each teacher took ownership of one lesson, facilitating distributed leadership while ensuring coherence through shared review sessions. This collaborative creation process allowed for active modeling of activities, multimedia resources, and multilingual supports as a key element of asset-based pedagogy and guiding concepts.

Phase 2: Implementation - Enactment and Embedded Investigation Cycles

During the September implementation, the unit was taught across multiple 6th-grade classrooms. This phase corresponded to the Implementation and Investigation stages of the LE cycle, with nested micro-cycles occurring daily as teachers collected and responded to student data. Each lesson was engineered to generate formative data:

Lesson 1: BBQ discussions and Skittles activity yielded insights into students' prior knowledge and cultural connections.

Lesson 2: Five hands-on stations produced observation notes, student drawings, and exit tickets that captured conceptual understanding and engagement.

Lessons 3–4: CER writing and recipe analysis provided evidence of students' ability to integrate evidence and reasoning.

Lesson 5: Choice board artifacts allowed for differentiated demonstration of mastery.

Teachers engaged in daily debriefs, a form of rapid-cycle investigation that allowed them to adjust pacing, scaffolding, and language supports in response to student needs. The station-based lesson (Day 2) functioned as a nested LE micro-cycle within the broader implementation. Each station was a mini-experiment: students' interactions with materials (steel wool, vinegar and baking soda, milk and lemon) generated immediate feedback, which teachers used to scaffold understanding and prompt deeper inquiry. The unit's emphasis on family recipes, multilingual discussions, and culturally familiar phenomena exemplifies LE's commitment to equity and diversity (Baker et al., 2022). By leveraging students' cultural assets as foundational resources, the unit engineered more inclusive and accessible learning pathways.

Teacher Perceptions of the Co-Design Process and Its Impact on Multilingual Learners

All three teachers highlighted significant increases in student engagement, which they attributed directly to the phenomenon-driven, culturally anchored design of the units. Ms. Herminia connected this engagement to opportunities for personal and cultural connection, explaining that the lessons allowed students to “share their knowledge about what they have personally experienced too.” Ms. Francisca similarly observed high involvement during multimodal activities such as the interactive word wall, where students “went up there and they placed it themselves after we did the reading. It gave them a little chance to read it, connect.” These observations underscore how the co-design process, specifically the intentional integration of translanguaging spaces and asset-based phenomena, which facilitated deeper intellectual and emotional investment from linguistically diverse students.

Teachers consistently described the co-design process as evolving a sense of ownership and adaptive expertise. Ms. Moira’s reflection - “These lessons have kind of become my babies” -epitomizes the shift from implementer to author. This agency manifested in thoughtful preparation, proactive planning, and real-time adjustment. Ms. Francisca, for instance, rated her preparation as 10 because she had “everything very well-prepared prior… in little cups… to maximize our time.” Similarly, Ms. Herminia emphasized the need to strategically purpose time and resources, stating, “If I have only forty-five minutes, realistically, I know I’m probably at best gonna get 30 to thirty-five.” These reflections illustrate how the iterative codesign cycle promoted teacher ownership, pedagogical adaptation, and responsiveness to contextual constraints as a core objective of learning engineering.

Teachers provided preliminary evidence of student learning, particularly in science content and language development. Ms. Herminia noted that chemical changes were “one of my higher performing standards… The average is 74.7.” She also highlighted growth among emergent bilingual students, sharing an example of a student who “got a 31.3… his second test… he had a 69.2. He made a big jump.” She explicitly connected this progress to the dual-language and translanguaging approach used in the co-designed unit, observing, “I can clearly see that in my students because they are brilliant in both languages.” However, teachers also pointed to areas for improvement, particularly in scientific discourse and reasoning. Ms. Francisca, suggested, “I do think that we could have spent more time on a reading aspect so that they could talk more… definitely more of the reading on the explain day. With more student discourse for them to defend.” This feedback underscores the importance of iterative refinement - a hallmark of the nested learning engineering cycle - to better integrate language and science sensemaking practices.

Discussion

This study reveals that a learning engineering approach, when deeply rooted in co-design and nested, iterative cycles, is a transformative pedagogical and relational practice that repositions teachers as authors, students as cultural and intellectual contributors, and science as a site of engagement and belonging. Our work moves beyond theoretical aspiration to demonstrate how equity-driven design can be systematically engineered into the co-design science lesson planning for multilingual learners.

The co-design process we implemented functioned as a powerful form of situated professional learning, one that refined what Ms. Moira described as lessons that became “my babies.” In a field often constrained by scripted curricula and compliance-oriented professional development, our model enabled teachers to engage in the “messy work” of pedagogical design-negotiating relevant phenomena, core science and engineering practices, language and discourse scaffolding for MLs, and integrating student language and cultural resources. It embodies what Baker et al. (2022) identify as “Better Engineer Learning System Implementation in Schools” as a process that honors teacher wisdom as essential to scalable, sustainable innovation.

The choice to anchor the unit in Texas BBQ and cooking was a deliberate engineering decision emerging from teacher insight and collective community knowledge. This phenomenon served as a cultural and cognitive entryway, facilitating students to connect abstract concepts of physical and chemical change to embodied, familial, and community practices. Ms. Herminia’s observation that students were “captivated”, and Ms. Francisca’s note of their engagement with multilingual word walls underscore how culturally responsive design is also cognitively engaging design. When students see their familiar languages, recipes, and lived experiences validated as scientific resources, science itself becomes a space of identity assertion, belonging, and intellectual power. This aligns directly with learning engineering's call to "Support Diversity and Enhance Equity" by moving beyond one-size-fits-all interventions toward contextually-grounded, asset-based learning experiences.

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