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Leveraging Funds of Knowledge through Engineering Activities for Latino/a Students in Dual Language Contexts (Fundamental)

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Introduction

Engineering education is a critical domain necessary to foster innovation and address complex global challenges, yet it remains constrained by traditional ideologies that overlook the diverse linguistic and cultural resources students bring to the field [1, 2]. Current research has increasingly called for more focused exploration of the role language plays in shaping engineering education, particularly in dual language contexts [2-4]. Despite the growing number of students classified as English Learners[1] (ELs) in the U.S. over the past 10 years [4], the intersection of language and engineering education remains underexplored, perpetuating the notion that linguistic practices and engineering content should remain separate [2, 5]. This separation not only marginalizes students from culturally and linguistically diverse backgrounds but also limits the field's potential for fostering inclusive and transformative learning experiences.

The prevailing ideology that language and engineering must operate in isolation, unfortunately, has had profound implications for educational practices. From early elementary school, students are often discouraged from using their full linguistic repertoire in STEM activities, reinforcing the idea that bilingualism is a barrier rather than an asset [6-8]. This approach fails to recognize the ways in which bilingualism and cultural identity can enrich the learning process. For instance, bilingual students often demonstrate enhanced cognitive flexibility, creativity, and problem-solving skills [2, 9, 10]—qualities that are highly valued in engineering. However, when these linguistic and cultural resources are excluded from the learning environment, students are denied opportunities to engage meaningfully in engineering.

This oversight is particularly troubling given the increasing diversity of student populations in many educational contexts. Emergent bilinguals [11, 12] represent a significant and growing demographic in schools, yet their experiences in STEM education often reflect systemic inequities [13, 14]. The exclusion of students' linguistic resources not only undermines their sense of belonging but also reinforces deficit perspectives that view bilingualism as a challenge to be overcome rather than an asset to be leveraged [15]. These deficit ideologies perpetuate a cycle of underrepresentation and disengagement, as students from linguistically diverse backgrounds are less likely to pursue and persist in STEM fields [4].

By embracing students' linguistic and cultural identities, educators can create more dynamic and inclusive learning environments that reflect the collaborative nature of engineering practice. Furthermore, integrating language into engineering education can provide students with a more holistic understanding of the field, emphasizing its social and cultural dimensions alongside its technical aspects. This paper seeks to address the critical gap in research on the intersections of language and engineering education. This study was guided by the research question, "How and

[1] While "English Learner" is the official classification used in educational policy and documentation, we use the term "Emergent Bilingual" to more accurately and affirmatively describe students' developing bilingualism and linguistic strengths from an asset-based viewpoint.

in what ways does the integration of bilingualism and cultural identity at the elementary level promote identification and engagement in engineering?"

Our goal was to challenge the traditional separation of language and STEM content while seeking to highlight the ways in which bilingualism and cultural identity can serve as valuable resources for fostering access to engineering, particularly early on (i.e., at the elementary level). This paper contributes to a broader reimagining of engineering education as a more inclusive and socially responsive field, capable of addressing the needs and aspirations of all students.

Theoretical Framework

This study is grounded in a theoretical framework that integrates Funds of Knowledge (FoK) and bilingualism to examine how linguistic and cultural resources can enhance engagement and access in engineering education. Together, these concepts provide a lens for understanding how students' lived experiences, linguistic repertoires, and cultural practices can be leveraged to challenge deficit perspectives and foster more inclusive learning environments.

The concept of FoK, developed by Moll et al. [16], refers to the historically accumulated and culturally developed knowledge and skills that individuals and communities use to navigate their daily lives. This framework challenges deficit ideologies by emphasizing that all students, including those from marginalized backgrounds, bring valuable resources to their learning environments [17]. In the context of engineering education, FoK highlights the ways in which students' cultural and community-based knowledge can inform problem-solving, creativity, and innovation [18-20]. For example, a student from a farming community might draw on their understanding of irrigation systems or sustainable practices when engaging in engineering design tasks [19]. Recognizing and integrating these funds of knowledge into the curriculum not only validates students' identities but also broadens the scope of engineering education to include other ways of being, knowing and doing.

Bilingualism, as both a cognitive and sociocultural phenomenon, further enriches this framework by highlighting the unique skills and insights that emerge from navigating multiple linguistic and cultural contexts [7, 9]. Research on bilingualism has shown that bilingual individuals often possess draw from their linguistic repertoires for problem-solving and sense-making [7, 8, 21]. These skills are directly relevant to engineering, where innovation often requires the ability to approach problems from multiple perspectives and adapt to complex, dynamic situations. Additionally, bilingualism is deeply tied to cultural identity [22], shaping how individuals interpret and interact with the world. In dual language contexts, students can draw on their full linguistic repertoire to articulate ideas, collaborate with peers, and engage in critical conversations about engineering practices.

Integrating FoK and bilingualism into engineering education challenges the traditional separation of language and STEM content, which has historically marginalized linguistically diverse students [2, 3, 5]. This separation is rooted in monolingual ideologies that prioritize English as the language of instruction and devalue other linguistic practices [3]. By contrast, a FoK and bilingualism framework recognizes that language is not just a tool for communication but also a means of constructing and sharing knowledge. For instance, students might use their home

language to explain complex engineering concepts, draw analogies from their cultural practices, or collaborate more effectively with peers. These practices enrich the learning process and demonstrate the value of linguistic diversity in engineering.

This theoretical framework also emphasizes the importance of creating spaces for critical conversations about the role of language and culture in engineering. By fostering an environment where students can reflect on how their linguistic and cultural identities intersect with their engineering experiences, educators can help them develop a critical consciousness about systemic inequities in STEM [14, 23]. This aligns with Freire's concept of *conscientização* [24, 25], which calls for the development of critical awareness, motivation, and action to challenge oppressive systems. Through this lens, FoK and bilingualism are not only tools for enhancing individual learning but also mechanisms for transforming engineering education into a more equitable and accessible field.

Methodology

This study utilized a qualitative research design to explore how a bilingual engineering curriculum fostered the integration of students' funds of knowledge and bilingualism within the context of the engineering design process. The program was conducted over one week and was structured to connect engineering concepts to the lived experiences of students. The one-week program was implemented at *Escuela STEM* (pseudonym), a Title I dual language elementary school classroom in South Central Texas. The school has a partnership with the local public university, and the principal at the school offered the space to recruit teachers interested in the project. The first author of this paper approached the second author, who was a 5th-grade teacher at the time at *Escuela STEM*, to collaborate on this project. The second author of this paper had been teaching at *Escuela STEM* for several years and self-identifies as Mexican American, whose cultural, linguistic and lived experiences are commonly shared with those of her students.

The demographic composition of the school was approximately 96% Latino/a/x, with the majority of the student population were native Spanish speakers (i.e., Spanish L1, English L2). Students in the classroom also represented demographics similar to those of the school. A total of 20 students (11 males and 9 females) consented to participate in the one-week implementation of the curriculum after assent and consent forms were obtained. It is important to note that although the curriculum was created in both English and Spanish, the majority of the time students preferred to engage in conversations and complete the activities in Spanish.

The bilingual engineering curriculum consisted of 4 different modules aimed at students aged 8-12, offering an engaging way to explore the engineering design process. It is important to note that the curricular materials were originally designed as part of an out of school program [26], but were later aligned with Texas state standards to be implemented in the classroom. The curriculum emphasized real-world problem-solving while encouraging students to leverage their Funds of Knowledge, connecting their learning to personal experiences and cultural backgrounds [26]. By combining digital resources with hands-on activities, the curriculum promoted teamwork as students collaborated to brainstorm ideas, build prototypes, and iterate through testing and redesigns. The four modules in the curriculum, each designed for ten sessions, included: (1) Discover the Design Process/Descubran el proceso de diseño; (2) Explore Pulley

Systems/Exploren las poleas; (3) Create Your Own Engineering Challenge/Creen su propio desafío de ingeniería; and (4) Showcase Your Work/Expongan su trabajo. At the end of the implementation, students participated in a classroom discussion where they presented their designs.

Data Collection

A key component of this program was the integration of bilingual communication, as students prepared presentations in both English and Spanish to explain their projects. This bilingual approach was a deliberate strategy to blend content and language learning within the context of engineering. Thus, qualitative data was collected in the form of observations, focus groups, and audio-recordings. This paper focuses primarily on data collected from Module 3, "Explore Pulley Systems/Exploren las poleas," because it provided rich data that demonstrated the interplay between bilingualism and funds of knowledge as students discussed their engineering problems. During this module, students were encouraged to observe and identify the challenge presented to them and test their prototypes. The activity initiated with different scenarios where the students were asked to look around in their school to see the use of pulleys in general, where they identified how these are used in different mechanisms (e.g., window blinds, flag pole, etc.). This activity served as a means of activating their funds of knowledge by allowing students to connect engineering problem-solving with relatable, real-world applications.

Following the initial presentation of the material, students worked in collaborative groups to brainstorm potential engineering solutions to the problems they were given: creating a prototype of a mechanism that could help raise a flag at least 24 inches. These collaborative sessions were designed to promote peer interaction, critical thinking, and the integration of diverse perspectives. Students then prepared presentations in both English and Spanish, explaining their engineering solutions and the reasoning behind their designs. This bilingual strategy was intentionally implemented to blend language learning with engineering content, allowing students to use their full linguistic repertoire to articulate ideas, collaborate effectively, and engage deeply with the subject matter.

The first author conducted detailed observations of the activity implementation, collaborative group work, and bilingual presentations. These observations focused on students' interactions, problem-solving approaches, and the ways in which they incorporated their linguistic and cultural resources into the engineering activities. He also conducted a focus group with students at the conclusion of the implementation to gather their reflections on the activities. These discussions provided insights into how students perceived the integration of their funds of knowledge and bilingualism in the engineering context, as well as the challenges and benefits they experienced. Finally, students' artifacts were also collected to identify how students used their funds of knowledge and linguistic repertoires to engage in sense- and meaning-making.

Data Analysis

The collected data were analyzed using multimodal discourse analysis [27-29], a method that examines how various modes of communication—such as language, gestures, visuals, and spatial arrangements—are used to convey meaning and support learning. This approach was particularly

well-suited to the study's focus, as it allowed for a nuanced examination of how students' linguistic and cultural resources were reflected in their interactions and project work.

The analysis of the data involved several steps. First, the audio-recordings and observation notes were transcribed and coded to identify recurring themes [30] related to the integration of funds of knowledge, bilingualism, and engagement in the engineering design process. Second, multimodal elements such as sketches, diagrams, and visual aids used in the presentations were analyzed to understand how they contributed to students' meaning-making and learning. Finally, the focus group transcripts were examined to capture students' perspectives on the program and its impact on their understanding of engineering concepts and their sense of belonging in engineering.

Results and Discussion

The results of this study reveal critical insights into how integrating bilingualism and funds of knowledge into engineering education can transform student engagement and perceptions of engineering. The findings highlight the potential of culturally and linguistically responsive approaches to create more inclusive and empowering learning environments. Below, we discuss the key themes that emerged from the data: the relevance of engineering to students' lives, the development of ownership and agency, and the role of bilingualism in reshaping STEM education narratives.

Engineering as Relevant to Students' Lives

One of the most significant findings of this study was the way students were able to connect engineering concepts to their own lived experiences. The module itself served as a pivotal moment in this process, as students identified real-world applications in their local environment that resonated with their daily lives. For example, students identified how pulleys were used in different mechanism while also pointing out issues that went beyond thinking about problems from just a technical perspective, such as the impacts of not providing maintenance to these mechanisms. For instance, Juan (pseudonym) pointed out that while there are pulleys in the entrance of the school being used for the flagpole, it had never been used because it constantly gets stuck and it has corroded. He mentioned, "we don't we have a flag because – nobody knows. I know it has been like we dropped the ball. They're like, there's – No, no flags there."

These observations also led to a nuanced conversation about how other areas of the school are also being affected by corrosion primarily due to the high humidity in the region. Then, students continued to relate this engineering problem to other issues such as the impacts of corrosion on bridges, doors, and fences. In particular, one student, Yaneli (pseudonym), talked about how humidity can also impact the growth of mold: "*Si no se protégé bien la pared puede hacer que crezca moho y es malo*" (if it a wall is not well protected it creates mold and is bad).

These observations demonstrated their ability to critically analyze their surroundings and frame these challenges as engineering problems requiring not just an understanding of mechanisms (i.e., technical understanding) but also an analysis of how different factors impact engineering solutions. Moreover, Yaneli's example illustrates how students used their bilingualism as a

resource for making sense of complex engineering concepts by drawing on both languages to articulate their ideas and connect them to lived experiences. Yaneli's use of Spanish to explain how humidity can lead to mold growth not only showcases her linguistic practices but also demonstrates her understanding of how environmental factors contribute to structural degradation. By discussing how corrosion affects various elements in their community—such as bridges, doors, and fences—students positioned engineering not as an abstract discipline but as one deeply intertwined with their everyday lives. This highlights how bilingual students engage in authentic, context-rich sense-making, demonstrating that their linguistic practices and lived experiences are valuable tools in engineering learning and meaning-making.

This relevance to their lived experiences shifted students' perceptions of engineering from an abstract, distant field to a practical and meaningful discipline. By engaging with problems that were personally significant, students were not only more motivated to participate but also better able to see themselves as active participants in engineering. This aligns with the concept of funds of knowledge, which emphasizes the importance of drawing on students' cultural and experiential knowledge to enhance learning. These findings suggest that when engineering education is grounded in students' realities, it becomes more accessible and impactful, particularly for those from historically marginalized backgrounds [19, 31-33].

Development of Ownership and Agency

Another finding was the development of a strong sense of ownership and agency among students. Through the collaborative nature of the group work and the hands-on, project-based approach, students were encouraged to take the lead at every stage of the design process. They were not just passive recipients of knowledge; instead, they were active participants in identifying problems, brainstorming potential solutions, designing prototypes, and presenting their ideas. This process of engagement instilled a deep sense of empowerment in the students, as they recognized their ability to see engineering as a way to participate in broader discussions about their communities. The awareness that their ideas and solutions could have a tangible impact on their surroundings gave them a sense of purpose and responsibility.

The bilingual aspect of the program played a crucial role in this sense of empowerment, while the teacher played a pivotal function in creating that space for students to feel empowered. After an interview with the teacher, she reflected about the significance of using not only bilingualism but engineering as an empowerment tool in the classroom. She observed that the engineering challenges did not just teach technical skills but offered students an opportunity to step into leadership roles, build self-confidence, and support each other. After a discussion about how students supported each other, the teacher reflected:

> I love that you noticed that [one student was supporting another] because that student that was supporting [the other student] is a low performing student, and [the engineering activity] gave that that student the opportunity to be a leader and to be like, in charge of something… And she struggles, like, really hard …but she shined so bright that day and that week. And not only that, but she made the space for [the other student] as well.

This moment encapsulated the power of the program to create opportunities for students to (re)claim their agency in the classroom and conducting these activities. For this particular student, the chance to take ownership of an engineering task allowed her to transcend her previous academic struggles and step into a leadership role. The engineering challenges, often perceived as difficult or intimidating, became a platform where she could demonstrate initiative, resilience, and creativity—qualities that are often overlooked when students are solely assessed through traditional metrics, particularly when it comes to STEM settings [5, 13].

Moreover, the student's newfound sense of leadership did not exist in isolation. Her role as a leader extended beyond her own personal success; it allowed her to uplift and empower a peer, creating a ripple effect of support and collaboration within the classroom. By making space for her classmate, she not only reinforced her own confidence but also helped foster a cooperative, supportive learning environment. This mutual support among students reflects the underlying values of the bilingual curriculum: that empowerment in STEM is not just about individual success but also about collaboration, community, and shared growth. The teacher's recognition of this dynamic, where a student who typically struggled academically became a leader and mentor, underscores how powerful it can be to view engineering as an activity grounded in everyday experiences. In this context, engineering served as a vehicle for a student to feel reflected in the curriculum and take ownership of their work.

Bilingualism as an Asset in STEM Education

The integration of bilingualism into the program was not just a practical adaptation but a deliberate strategy aimed at challenging the monolingual ideologies that often dominate STEM education [3]. In traditional STEM settings, there is an implicit assumption that English is the sole medium for learning and communicating scientific and technical ideas, which can alienate bilingual and bicultural students [6, 14]. This program, however, recognized the value of students' full linguistic repertoires, embracing both English and Spanish as tools for meaning-making. The findings from the program illustrate how language, as a fund of knowledge, can be a transformative asset in engineering education, reshaping the way students engage with and understand engineering concepts.

One example is how the students used their bilingualism to explain, (re)frame, and solve problems. Figure 1 below shows how Mario (pseudonym), one of the students in the class, uses both English and Spanish to label the different pieces of his pulley sketch, including words like "*cuerda*" (rope). He also shifted between Spanish and English as he explained what was working (i.e., "it is standing")) and what needed to be fixed (i.e., "*necesita la pulley y cuerda*" (it needs the pulley and rope), "*necesita bandera"* (needs the flag)). The ability to problem-solve by shifting between languages allowed students to frame and reframe problems from multiple perspectives. Similarly, during brainstorming sessions, students would frequently switch between English and Spanish to clarify ideas, express complex concepts, or draw analogies from their own experiences. This linguistic fluidity allowed them to approach problems from different angles, making connections that might not have been apparent if they were confined to a single language.

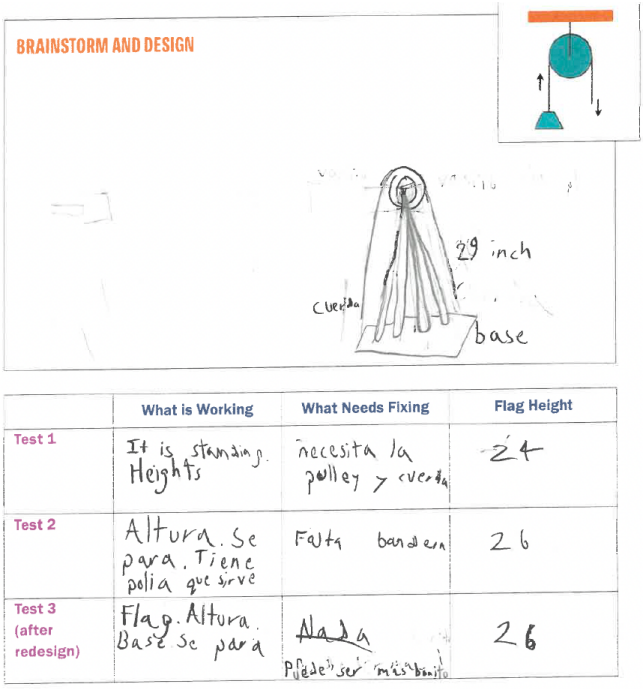

Figure 1. Multimodal artifact created by student illustrating how sense- and meaning-making occurred in a bilingual context.

Moreover, bilingualism served as a bridge to enhanced critical thinking. In this bilingual environment, students assessed and analyzed engineering problems through multiple lenses—linguistic, cultural, and technical. The activities encouraged students to draw from their funds of knowledge through guided inquiry, often requiring them to adapt their ideas. For example, during the focus group the students indicated how they drew from their own funds of knowledge to think about how to create a solution that would not waste a lot of material. When asked about how they learned about being resourceful, José (pseudonym) commented in this interaction with the teacher:

> Teacher: *¿Hay personas en su familia o en su casa que tengan trabajos que ustedes podrían considerar como relacionados a la ingeniería, o que les ayude a pensar en cómo resolver problemas?* (Are there people in your family or at home that have jobs that you could consider to be related to engineering, or that could help you think about how to solve problems?)
>
> José: *Si, yo le ayudo a mi papá a hacer trabajos en carros y casas.* (Yes, I help my dad work on cars and homes)
>
> Teacher: *¡Ah! ¿Qué hace con los carros? ¿Arregla carros?* (Oh! And what does he do with the cars? Does he fix cars?)
>
> José: *Si los arregla así como, así, que lo va a comprar para un* (yes, he fixes them, like, as if they are going to buy for) – is going to buy for a small amount and then he's going to fix it and it's going to be for a bigger amount.

In this exchange, José shares that he helps his father with hands-on tasks, such as working on cars and homes. This response highlights a crucial point: engineering problem-solving is not confined to a classroom or laboratory setting. José's family experiences with car repair and home improvement reflect the type of practical, applied engineering work that is integral to many communities, particularly in trades and skilled labor. When José describes his father's work, he explains the process of buying a car for a small amount, fixing it, and then selling it for a higher price. This process mirrors key engineering principles, such as design, repair, and optimization, and it highlights how students can connect real-world problem-solving with the academic content they encounter in the classroom. Moreover, this example also highlights the nature of funds of knowledge, which involve the use of skills, practices, and knowledge for well-being and survival [16, 34].

Furthermore, this exchange exemplifies the power of bilingualism in supporting meaning-making in engineering. As José switches between Spanish and English, he is not just translating words; he is also translating ideas and concepts that are rooted in his personal, cultural, and linguistic context. The way he describes his father's work—*"arregla carros"* (fixes cars) and *"va a comprar para un"* (is going to buy for)—shows how bilingual students navigate complex ideas across languages. The ability to fluidly switch between languages allows students to express concepts that may be more familiar or accessible in one language, thus enhancing their understanding and communication of engineering principles.

On a social level, the bilingual aspect of the program played a pivotal role in fostering inclusivity and collaboration. Allowing students to present their engineering solutions in their home language—whether it was Spanish, English, or a mix of both—created a more equitable learning environment where all voices were heard and valued. This was especially important for bilingual students who often face the pressure to conform to English-only norms in traditional educational settings. In this program, however, bilingualism was not just accepted but encouraged as an asset that enhanced the learning process. When students presented their work in Spanish, they were able to speak more confidently and comfortably about their ideas, ensuring that their contributions were not minimized or invalidated. By providing a space where students could articulate complex engineering concepts in the language in which they felt most comfortable, the program empowered them to take ownership of their learning and contribute more effectively to group discussions.

Implications for Engineering Education

The findings of this study have important implications for engineering education, particularly in contexts with culturally and linguistically diverse student populations at the elementary level. First, the integration of funds of knowledge into the curriculum highlights the importance of grounding engineering education in students' lived experiences. By connecting engineering concepts to real-world problems that are meaningful to students, educators can enhance engagement and foster a sense of relevance and purpose in STEM learning.

Second, the use of bilingualism in both content and communication underscores the need to challenge monolingual ideologies in STEM education. Recognizing and valuing students' linguistic diversity not only enhances their learning experiences but also promotes equity and

inclusion in engineering. This approach requires educators to rethink traditional teaching practices and adopt strategies that embrace the full linguistic and cultural repertoire of their students.

Perhaps one of the most powerful outcomes of the bilingual approach was the way it transformed students' perceptions of engineering as a profession. Traditionally, STEM fields have been viewed as domains where English proficiency is required, reinforcing the idea that students must conform to a specific linguistic and cultural standard to succeed. However, by demonstrating that engineering can be practiced and communicated in multiple languages, the program disrupted this notion. The bilingual format of the curriculum showcased that engineering is not a monolithic field but one that is accessible to a wide range of linguistic and cultural backgrounds. This shift is particularly important in dual-language contexts because students' linguistic diversity has been traditionally overlooked or undervalued. By embracing bilingualism in engineering education, the program helped dismantle the barriers that have historically kept bilingual students from fully participating in STEM.

Finally, the development of ownership and agency among students highlights the transformative potential of culturally and linguistically responsive teaching practices. When students are empowered to take the lead in their learning and see their identities as assets, they are more likely to persist and succeed in STEM fields. This is particularly important for students from historically marginalized backgrounds, who have often been excluded from or underrepresented in engineering.

Conclusion

This study demonstrates the transformative potential of integrating funds of knowledge and bilingualism into engineering education. By connecting engineering concepts to students' lived experiences and embracing their linguistic diversity, engineering education has the potential to foster a sense of relevance, ownership, and agency among participants. These findings challenge traditional deficit perspectives and highlight the importance of creating inclusive learning environments that value and leverage the diverse resources students bring to STEM learning spaces.

The findings suggest that bilingualism can serve as a powerful tool for inclusion and empowerment in engineering education. By making room for multiple languages, the program not only enriched students' cognitive and social engagement with engineering but also contributed to a broader reimagining of what engineering education can look like in a diverse society. Rather than seeing bilingualism as an obstacle to be overcome, the program embraced it as a resource that enhanced students' ability to think critically, collaborate meaningfully, and communicate effectively in a globalized world. This approach not only benefits bilingual students but also helps reshape the STEM landscape by making it more inclusive, equitable, and reflective of the diverse communities that it serves.

Moving forward, there is a pressing need for more research and practice that explores the intersections of language, culture, and engineering education. By continuing to challenge exclusionary barriers and reimagine engineering as a more inclusive and equitable field,

educators can create opportunities for all students to thrive and contribute meaningfully to the discipline.

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