Language Fusion in the Lab: Unveiling the Translanguaging Strategies of Spanish-Speaking Students in Biosystem Engineering Technology and Science

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Background and research question

Modern classrooms are a melting pot of cultures and languages, presenting teachers with the challenge of explaining scientific and engineering concepts to a diverse student body. To bridge language gaps, educators are turning to adaptive methods like 'translanguaging', which taps into students' native and secondary languages to boost their grasp of scientific ideas.

Research [1] confirms that this approach enhances students' scientific understanding. To foster a supportive teaching environment, a workshop was recently held for teaching assistants, which Han et al. [2] found effective in building community and attracting international students seeking to improve their teaching skills. In the work by Pierson [3] the concept of translanguaging is elucidated as a dynamic process where individuals leverage diverse languages and modes for the purposes of meaning-making and expression, particularly within the context of bilingual and English-dominant STEM classrooms. This process is posited to facilitate learning by allowing for a more inclusive and accessible approach to education. Furthermore, Pierson delves into the intrinsic relationship between translanguaging and the scientific practice of modeling, highlighting the importance of multimodality—where various modes of communication are employed—in constructing and interpreting scientific models. The exploration into how translanguaging can be integrated with scientific modeling in education underscores the potential for enhanced learning experiences. By advocating for a syncretic design approach, Pierson suggests that combining everyday practices with academic disciplines through translanguaging can foster new forms of knowledge and expertise, thereby enriching the educational landscape in English-dominant STEM settings.

In engineering education, [4] showcased a tutoring initiative that significantly bolstered the writing abilities of multilingual doctoral candidates through customized language support, including handouts and videos. [5] These authors championed a revamped engineering curriculum that aligns with students' cultural and digital strengths, advocating for interactive, project-based learning to develop soft skills and a global perspective. The integration of technology in language learning, particularly in biosystems engineering education, is transforming how students from diverse linguistic backgrounds engage with academic content. This approach is especially relevant for those learning English as a second language, where technology plays a crucial role in facilitating language acquisition and translation. They emphasize how technology not only aids in translation but also offers a wealth of online resources, enhancing accessibility and flexibility in learning [6].

These studies collectively support the idea that embracing multilingualism in education can greatly improve understanding in complex fields like science and engineering. Tailored educational programs have proven successful in enhancing the academic writing of multilingual engineering students, and innovative teaching methods that integrate cultural and digital knowledge are key to preparing engineers for a globalized workforce For educational progress,

teaching assistants should approach their role with empathy and adaptability, recognizing the varied cultural backgrounds and learning preferences of students. This inclusive mindset not only enriches the learning experience but also leverages students' existing skills, creating a more effective educational environment [7]-[8].

Research Approach and Data Gathering Techniques & Examination of Data

This study focuses on exploring the integration of technology with translanguaging in biosystems engineering laboratories, particularly among graduate assistants from Spanish-speaking backgrounds. Its primary objectives are to uncover the complex dynamics between translanguaging and technology use during laboratory sessions and to assess both the benefits and challenges of technology in educational contexts. The study uses storytelling to understand the personal stories of four international students who all come from the same Spanish-speaking country and culture. Such narratives are critical for understanding the interplay between language (translanguaging) and technology in education, as highlighted in the works of [9]-[13]. These personal accounts will provide insights into the strategies and experiences of graduate assistants in blending technology with translanguaging, thereby contributing to teaching methods that cater to the linguistic, academic, and technological needs of international engineering students.

Our methodological approach includes collective autoethnography, as outlined by [14] and expanded by [15] and [16]. This technique allows for an in-depth collaborative analysis of our experiences, structured chronologically, and contextualized within broader social and cultural frameworks. It enables participant-researchers to introspectively consider their biases and perspectives while retrospectively writing and systematically analyzing their experiences. The study focuses on how three graduate assistants in biological engineering labs and one in educational studies write about and carefully examine their own experiences. They aim to create teaching methods that help international students who speak two or more languages and come from different backgrounds, especially in engineering. This includes looking into how using technology and mixing languages in the lab, especially for Spanish-speaking assistants, can help overcome difficulties and bring advantages.

One significant aspect of our study is the examination of how technology and translanguaging can benefit Spanish-speaking international students. This includes not only enhancing their learning of both content and language but also facilitating smoother interactions in a supportive environment for translanguaging. A study reinforces this idea, highlighting the positive impact of translanguaging in bilingual and immersion settings, such as improved task performance, content learning, and biliteracy skills development [17].

To examine the data, we employ a technique that involves engaging in detailed conversations with Guatemalan graduate students who are fluent in Spanish, treating them not merely as subjects of our research but as vital contributors to our study. The goal of these discussions is to gather detailed information about how they use multiple languages and technology in labs, with a focus on how they communicate and understand tasks. Following these discussions, we hold reflection meetings to go over and confirm the details gathered from the interviews. The findings

from these interviews will help us think about how to make future classroom experiences better suited for graduate student assistants from different language backgrounds. In December 2023, during our reflection meetings, we took a close look at our own experiences. Hector led group talks and interviews to study our experiences, especially the cultural parts in our life stories and research. We found important topics and patterns. Hector used MAXQDA, a tool for analyzing data, to organize these topics. Early topics included language use (Spanish and English), using technology, and our experiences as teaching assistants. More discussions and input from Elias helped refine these topics, leading to the creation of the findings section in our study.

Each writer added their own life story to this section, showing their background and role in the research. We used a thematic analysis approach, combining personal stories of learning biological systems engineering in English with our bilingual journey at an English-only school. This gave us deeper understanding of our teaching and research work.

The findings section starts with our personal stories, then moves to a detailed discussion and analysis of the themes we found. This layout lets readers get to know us first before exploring the main topics from our reflective sessions and group analysis.

Findings

Our stories

Hector's Story

I'm doing my Ph.D. in Curriculum Studies and new technologies at the University of Nebraska-Lincoln. My work involves teaching future high school teachers about using technology and bilingual education, with a strong focus on justice, dignity, and human rights. Before this, I taught at the Universidad de San Carlos in Guatemala and was an elementary school teacher. My research combines bilingual/multilingual education with technology, particularly in Mayan languages. I study literacy in Indigenous languages, explore gentle teaching methods, and examine how artificial intelligence is used in education. I also advise on biological systems engineering education.

In 2019, when I started my Ph.D., I met Heydi and Juan Carlos from the Biological Systems Engineering department. I also reconnected with Elias from the same department. We all share a Guatemalan background and speak Spanish, which brought us close. Together with Heydi, we worked to improve teaching assistant programs, focusing on using technology in teaching. We held workshops to promote collaboration between the education and biosystems engineering departments and co-wrote a paper on digital tools in classrooms, emphasizing team building. My work in biosystems engineering expanded, including summer projects like advanced manure management techniques, which Juan Carlos, a master's student, also worked on. This showed me how linguistics, technology, and biosystems engineering intersect, especially in using communication to improve technology in farming. Elias and I were part of an international students organization, helping students adapt to American culture and connect with American families. I organized cultural events and mentored students, which was key to our project's success in bringing together diverse skills and backgrounds.

Heydi's Story

I am Heydi Han, a Ph.D. candidate in Biological Engineering working as a graduate assistant in the Biological Systems Engineering department at the University of Nebraska-Lincoln. I started my bilingual journey during high school in Guatemala by attending English lessons every Saturday morning thanks to the resources available at the public university and the support from my parents. Several years later, I enrolled in a master's program at Oklahoma State University. This was my first experience taking classes in English, during which I learned to accept my accent and accommodate the extra time needed for reading and writing compared to my native language.

Reflecting on my academic journey, teaching has emerged as one of the most gratifying aspects of my graduate school experience. A particularly memorable experience was when I assisted in two undergraduate courses during a semester in Beijing China, in the fall of 2019. I provided English instruction to undergraduate students whose English was their second language.

Later, I was a teaching graduate assistant for "Engineering Properties of Biological Materials." The guidance of the faculty and my advisor's support have been key in teaching this course. I also received guidance from Hector on how to efficiently use technology tools to build community among students.

Language is vital in my life. Spanish keeps me connected to my culture, and English is essential for my career. In the engineering lab, I use Spanish with my colleagues and English for official instructions. Although I face challenges with complex English technical terms, I am improving through online tools like YouTube and the Merriam-Webster website. My bilingual skills are valuable in the lab's diverse setting, enabling me to connect with various students and create an inclusive atmosphere.

Technology is integral to my academic role, as I keep up with new lab equipment and innovative ways to teach engineering concepts using the latest technology. This has taught me the importance of technology in supporting education in multiple languages. I believe it is important for professors to communicate effectively with teaching assistants from different backgrounds, like myself. Providing training in communication techniques and accepting different accents would greatly benefit international students.

For instance, I combined my linguistic skills and technological savvy by utilizing YouTube and Khan Academy to prepare for a lab session, overcoming language barriers to guide students efficiently.

Ultimately, as a bilingual graduate assistant, I blend language, technology, and teaching methods, demonstrating how these elements unite various cultural and academic areas.

Juan Carlos' Story

I am Juan Carlos Ramos Tánchez, and my bilingual journey began with a short undergrad internship with the University of Tennessee working on sustainable agriculture. My advisor at

that time was from the US but spoke Spanish. His help was key, making me thrive through that internship as my English level was still deficient at that point.

My journey continued in a small town in Missouri. Fresh out of college with my bachelor's degree in hand, I found myself interning at a hog farm. This wasn't just a job; it was my introduction to agricultural engineering, a field that would shape my career. As I worked on the farm, I started dreaming of a deeper understanding of agricultural systems. I knew that a graduate degree was essential for this dream. So, during the evenings, I dedicated myself to learning English, preparing for the TOEFL exam, fully aware of its importance for my academic ambitions internationally.

Seeking advice, I connected with my network. A Nebraskan friend, with a background similar to mine, guided me through the process of applying for graduate assistantships in the US. This led me to an advisor who, coincidentally, had worked at the same Missouri farm.

My path took an exciting turn when I relocated to Nebraska for a Master's in Mechanical Systems Management. This wasn't just an academic shift; it was a cultural one as well. In Nebraska, I found a Spanish-speaking community, allowing me to mix Spanish and English in our varied conversations.

In the laboratory, I thrived in a bilingual setting. Among Spanish speakers, we usually used our first language for our deep discussions, a comfort zone for our free-flowing ideas. English, on the other hand, was essential for connecting with my advisors and English speaker in my lab, along with the broader audience. This bilingual environment mirrored my own life, blending my Hispanic heritage with my professional aspirations.

Elías' Story

My name is Boanerges Elías Bámaca Saquic. I have a background in chemical engineering and non-profit work, and I am currently a PhD candidate in Biological Engineering. My focus area is fermentation and biomass conversion to biomaterials and bioenergy. In my spare time, I enjoy listening to classical and folk music, reading old novels and philosophy books, and listening to podcasts. Growing up, I was taught that our Hispanic culture is a rich part of Western culture, which shapes my perspective on faith, education, family, and professional development.

I use my name, Boanerges Elías, as a reference point for the subtle differences in communication between local culture and my Guatemalan heritage. In Guatemala, it is common to use either your first or middle name. Here, some locals find it interesting that I prefer my middle name, Elias, over my first. Friends from Asian and African cultures have also remarked on the number of names I have. This is a simple yet telling example of how language is intertwined with my culture, history, and communication methods.

My journey to graduate school began without any knowledge of Nebraska. Fortunately, a close friend in Guatemala mentioned he had a friend in the Fulbright program in Nebraska. Through this connection, I learned the necessary steps to settle in Lincoln. For international students, such guidance is invaluable, even for seemingly trivial matters like locating the bus stop. We quickly became friends and formed a diverse social circle, including other Hispanics and locals.

Communicating with friends from Guatemala allows for deeper conversations. In Guatemala, we often lightly joke about stressful situations, perhaps a coping mechanism developed during the civil war and its aftermath. This might surprise people from different cultures, even Hispanic friends, who may perceive it as not taking things seriously. However, it is often a way of dealing with serious topics.

In my teaching role for a biological engineering laboratory and assisting in other courses, I have observed that Guatemalans, and maybe other internationals, often use English as if translating directly from Spanish, leading to amusing situations and further discussions. In engineering, the pragmatic and straightforward nature of scientific topics helps, though it gets challenging when adding nuance or developing narratives for experiments or engineering situations.

Graduate school in English has been a rewarding experience. I feel blessed. And even in Nebraska, Spanish is recognized, though not as widely spoken as in other Southern states. The blending of Spanish and Hispanic themes into the local culture over the centuries is evident. There are differences among Hispanic countries, yet we share many core values that facilitate rich, fluid conversations. Living here longer, I have noticed how similar our values and worldviews are to those of the local people in this wonderful Nation.

Insights and Reflections: Themes from Interviews and Reflections

Heydi and Juan Carlos, along with Elias and Hector, share stories that align closely with themes of language usage, especially the concept of translanguaging, adapting to and surmounting obstacles, and the advantages of being bilingual. Their experiences also highlight the role of technology in language assistance and echo the experiences of other international students.

Translanguaging in Academic Settings

All the participants in the research possess extensive bilingual skills and habits, which we use tactically and smoothly in our everyday activities. This helps us socialize and keep our connection with our language and cultural groups in Nebraska and our home country, Guatemala. A key theme in our research is translanguaging, the seamless blending of multiple languages for communication. This is vividly illustrated in the stories of Heydi, Juan Carlos, Elias and Hector.

Heydi, working in a lab, skillfully navigates between Spanish and English. She uses Spanish for collaborative planning and problem-solving with her Spanish-speaking assistants, while English is reserved for more formal teaching moments. Juan Carlos shows similar versatility, using Spanish for in-depth discussions and English when addressing a wider audience.

We add another dimension, describing how casual conversations with peers from similar backgrounds often involve a mix of English and Spanish. This linguistic blend extends beyond the classroom, strengthening friendships, alleviating stress, and enhancing empathy among peers during graduate school. It is a practice that enriches their shared cultural experiences, from food to customs, and bolsters their individual identities.

Another common theme was that in formal academic settings such as graduate classes and lab work with non-Spanish speaking peers, students often refrained from using Spanish or blending languages, choosing instead to communicate exclusively in English. Hector brought up that, “occasionally, when near a Guatemalan student, I might use a Spanish phrase and then ask for its English translation. This approach, rather than translanguaging, seems to stem from a concern that mixing languages might reflect poorly on their English proficiency and project an unprofessional image to peers and instructors. However, this can also be seen as a relaxed way of engaging and expressing themselves in both languages.”

Stories of Resilience and Adaptation in Academic Settings

In academic settings, the ability to adapt linguistically and culturally is crucial, as illustrated by the stories of Heydi, Juan Carlos, and Hector. Heydi's journey involved overcoming language barriers and self-doubt by utilizing online tools like YouTube and Khan Academy. These resources aided her in mastering technical English terms, demonstrating her resilience and determination. Juan Carlos's story mirrors this resilience; he balanced his job with a commitment to learning English, striving to pass the TOEFL exam. Both stories highlight the importance of adapting and being resilient in overcoming language obstacles.

The study of translanguaging in graduate programs reveals a challenging dynamic. Students actively made space for translanguaging, integrating their native languages into their learning process. However, they faced obstacles due to a strong preference for English-only policies in teaching and evaluation. To enhance the effectiveness of translanguaging methods, there is a need for creative integration of students' native languages into the curriculum, possibly through innovative approaches such as displaying multilingual posters in labs.

Hector emphasizes the opportunities academia offers for Spanish-speaking students to engage in public outreach projects. Such initiatives are particularly significant in places such as Lincoln, Nebraska, which is known for its linguistic diversity. It is noted that while the exact count of languages spoken in Lincoln is unknown, it is undoubtedly diverse. The city's public school district reports students speaking 52 different languages, reflecting the presence of over 30,000 immigrants and refugees from about 150 countries. This diversity stems from the U.S. Government recognizing Lincoln as a refugee-friendly city in the 1970s [18]. This multicultural environment highlights the importance of embracing linguistic diversity in educational settings, offering a rich ground for international students to integrate and contribute.

The Advantages of Bilingualism

In the context of linguistics and STEM education, the concept of bilingualism, particularly translanguaging pedagogy, emerges as a pivotal element in enhancing both academic and personal growth. This approach, as epitomized by the experiences of Heydi and Juan Carlos, underscores the profound impact of bilingual abilities in navigating and surmounting academic and cultural challenges.

Translanguaging pedagogy, a contemporary educational approach, advocates for the integration of students' native linguistic skills alongside the target language. This method, which is gaining

increasing recognition in the 21st century, allows students to utilize all their linguistic abilities in communication, thereby fostering a sense of belonging and improving their learning outcomes. It is particularly beneficial in multicultural and inclusive educational environments, where it facilitates cultural understanding and respect. By acknowledging and utilizing the diverse linguistic resources and rights of students, particularly international ones, this approach enhances learning outcomes and promotes cultural understanding [19].

The stories of Heydi and Juan Carlos underscore the multifaceted advantages of bilingualism in both personal and professional realms. Heydi's bilingual skills allow her to connect deeply with Hispanic students and those learning Spanish, thereby enriching the educational experience. Juan Carlos, on the other hand, sees bilingualism as integral to his identity, helping him navigate both academic and cultural environments effectively.

Bilingualism goes beyond simple communication; it is increasingly vital in our globally interconnected world, notably in adapting to various cultural contexts and in the international business sector. The concept of translanguaging, which involves mixing two languages, supports the idea that leveraging a student's native language can greatly enhance learning a new language and comprehending complex ideas. This approach is in line with modern educational theories, such as those proposed by [19] linguistic interdependence theory, which advocate for diversity and inclusivity in education.

The experiences of Heydi and Juan Carlos exemplify the importance of bilingualism and translanguaging in educational settings. They highlight its role in fostering personal and professional growth, as well as creating an inclusive, equitable educational environment. Bilingualism has been linked to enhanced executive functions, such as improved focus and task-switching abilities [20] which can be advantageous in mastering complex subjects such as science.

From our introspective discussions, Heydi, Elias, and Juan Carlos, observed enhanced problem-solving skills when thinking from the diverse perspectives offered by two languages. Research supports this, showing that multilingual students often exhibit superior problem-solving and memory capabilities [21]. Additionally, bilingualism encourages mental flexibility, cultural appreciation, and communicative sensitivity [22], qualities that are beneficial in collaborative and innovative scientific work.

Providing bilingual education and strong science foundations from an early age may therefore foster cognitive development and career success in STEM fields. Such educational approaches promote analytical thinking and communication skills, which are valuable across various professional contexts [22].

In the realm of Biosystems Engineering, and in scientific fields more broadly, cross-cultural collaboration is increasingly vital. The multilingual abilities exhibited by Heydi and Juan Carlos and Elias as well as the other international students around them are invaluable for such collaborations, especially pertinent to global challenges in agriculture, sustainability, and environmental management – the core focuses of Biosystems Engineering.

Linguistic Diversity as a Catalyst for Innovation in Biosystems Engineering

In the experiences of Heydi, Juan Carlos, and Elias linguistic diversity stands out as a crucial factor influencing scientific understanding and processes. Heydi's bilingualism in the lab not only deepens her grasp of complex scientific concepts but also bolsters her interactions with a diverse range of students and colleagues.

The increasing linguistic diversity in higher education, especially in science, driven by a surge in international student enrollment, offers both opportunities and challenges [23],[24]. This diversity injects new perspectives and a global dimension into scientific research, potentially catalyzing groundbreaking innovations and novel problem-solving methods. Yet, linguistic barriers may restrict full participation of international scholars in collaborative scientific projects. Addressing this, it is critical to enact support for linguistic diversity, including language instruction, translation services, and other academic supports for multilingually proficient students [23],[24].

Further, recognizing the significance of cultural diversity and cultivating effective communication strategies in this linguistically varied context is essential for universities. Utilizing the internationalization of higher education to enhance educational quality and tackle challenges in research, teaching, and community service is part of this process [25]. A shift towards sustainable human development, a culture of peace, and lifelong learning requires fostering a multicultural ethos that values and respects cultural diversity. International students frequently face hurdles in adapting to new cultural and linguistic environments, intensifying their academic and personal challenges [26]. Hence, providing support to help them overcome linguistic barriers and engage fully in collaborative work is vital.

Juan Carlos’s living arrangements also impacted on his language usage. Initially residing with Spanish speakers, he maintained his native language proficiency. However, moving into an English-speaking household led to reduced Spanish use, a reflection of the broader challenge in preserving native language in a dominant foreign linguistic environment. The arrival of more Spanish-speaking colleagues in the lab later revived the use of Spanish in professional discussions, demonstrating how language dynamics in the workplace can change based on team composition.

Juan Carlos’s professional linguistic journey is particularly intriguing. He encountered specific technical terms and concepts, like 'Grad School Advisor,' which he predominantly learned and used in English. When sharing these concepts with Spanish-speaking peers in similar fields, he often retained the English terms, exemplifying a common practice in many technical fields where English terminology is globally accepted.

These narratives underscore the essential role of linguistic abilities in linking abstract academic concepts with their practical applications. Heydi leverages her multilingual proficiency, augmented by digital tools, to deepen both her comprehension and pedagogy of intricate engineering theories. Similarly, Juan Carlos's bilingualism facilitates a more profound understanding of agricultural systems in a hands-on context.

In a reflective conversation, Elias highlighted his routine practice of code-switching: using Spanish within the familial setting, academic Spanish at his school in Guatemala, and English in a university environment in an English-speaking nation. He recognized this linguistic agility as a valuable asset, enabling him to adeptly manage various real-life scenarios. This capacity for linguistic adaptation not only illustrates Elias's seamless transition between different contexts but also emphasizes the broader implication of how multilingualism can significantly bolster problem-solving and communicative abilities across diverse settings.

The capacity to convey complex scientific ideas across different languages is particularly vital in disciplines such as Biosystems Engineering. This field frequently requires the explanation of intricate notions to a varied audience, which may not always have a technical background. Research indicates that the concept of translanguaging is instrumental in aiding students to not only grasp scientific notions more profoundly but also to hone their scientific competencies. This is largely achieved through collaborative efforts among peers within an interactive laboratory setting, as highlighted by [27].

Translanguaging empowers students by allowing the integration of various languages and communication methods, thereby enhancing the process of knowledge construction. This approach enables learners to collaboratively forge scientific understanding while simultaneously mastering the scientific lexicon. Moreover, translanguaging contributes to creating a more engaging and enjoyable learning atmosphere through the incorporation of playful and dynamic verbal interactions among students and educators. Illustrative of this approach are instances where students collaboratively engage in scientific problem-solving during laboratory sessions, employ interactive discussions to decode experimental findings, and partake in vibrant exchanges that infuse humor and vitality into the learning environment [27].

Building on the significance of linguistic proficiency, it is crucial to weave cultural diversity into both academic and social realms. Universities play a pivotal role in cultivating a multicultural ecosystem, fostering an environment where individuals from diverse linguistic backgrounds are not only acknowledged but also celebrated. By organizing cultural events, encouraging intercultural dialogue, and enabling meaningful interactions between students and faculty from varied cultural origins, universities can create a more inclusive atmosphere. Such initiatives, as advocated by [28] and [29], are instrumental in promoting a sense of belonging and respect among the university community, thereby enhancing the educational experience for all.

Expanding upon the narratives of multilingualism's impact in academia, Hector's reflections on bilingual education further illuminate the profound benefits of language exchange programs. These initiatives, designed to facilitate interaction between learners proficient in different languages and native speakers, are highly beneficial. They not only enhance linguistic skills but also foster a deeper understanding and appreciation of diverse cultures, as [29] have observed.

The commitment to integrating linguistic diversity and cultural exchange into the fabric of higher education, especially within scientific disciplines, significantly enriches the educational experience. It promotes a spirit of collaboration, drives innovation, and nurtures a sense of community. Emphasizing the importance of linguistic diversity and cultural inclusivity is crucial

for fostering an academic environment that is conducive to both scientific advancement and personal growth. According to [29], adopting a bilingual approach in education opens doors to innovative problem-solving techniques and introduces a wealth of diverse perspectives into research and pedagogy, thereby enhancing the overall quality and impact of academic endeavors.

Enhancing Inclusivity in Academic Settings

The integration of linguistic diversity into Biosystems Engineering exemplifies how inclusivity can be fostered in academic disciplines. When educators like Heydi and Juan Carlos utilize both their native languages and English, they create environments that are welcoming and inclusive for students and colleagues from diverse backgrounds. This inclusivity is vital in academic and research settings, as it encourages a wide range of perspectives, which are crucial for the advancement of any scientific discipline, including Biosystems Engineering.

However, the broader application of translanguaging in higher education faces significant challenges [30],[31]. These challenges include a lack of awareness and understanding among educators, limited resources and training for implementing translanguaging, and institutional policies that often favor monolingual instruction and assessment. Overcoming these challenges is essential for nurturing linguistic diversity in universities, creating an environment that not only accommodates but also values the diverse linguistic backgrounds of students and faculty [29],[32],[33].

To address these barriers, universities can take proactive steps. Providing professional development opportunities for educators to learn about the benefits of translanguaging in the classroom is one such step. Another is allocating resources for the development of bilingual or multilingual instructional materials and assessments, which can create a more inclusive academic environment. Such initiatives support students in their language development and enhance their engagement in academic tasks [23],[34],[23].

Furthermore, establishing language support programs that offer tutoring, workshops, and translation services is crucial for ensuring that all students, particularly multilingual learners, have equitable access to education. Investing in resources such as translation services and language support programs, along with the development of teaching materials that incorporate translanguaging practices, further supports this goal.

In Biosystems Engineering, the diverse skills and perspectives of Heydi, Juan Carlos, and Elias, guided by Hector’s interdisciplinary approach, redefine student experiences. Integrating linguistic diversity goes beyond communication, enriching the field with innovative solutions and cross-cultural understanding. Their stories illustrate how diverse linguistic skills bridge the gap between theory and practice, cultivate an inclusive research environment, and ultimately enhance the educational experience for all students, expanding their horizons beyond traditional coursework.

Final Remarks

This study explores the impacts of translanguaging and bilingualism within educational settings, offering insights into how they play crucial roles in fostering academic and social integration, resilience, and innovation. This study also examines how translanguaging and bilingualism in education impact academic and social integration, resilience, and innovation. It emphasizes the importance of recognizing and using students' language skills fully. People like Heydi, Juan Carlos, Elias, and Hector, who are international graduate students fluent in both Spanish and English, serve as examples. Additionally, it provides a platform for hearing firsthand stories from influential figures in academia.

These individuals usually work diligently behind their desks, preparing for academic success, and often go unnoticed until they present at conferences or in small lab sessions. They inspire others to share their stories in fields related to academic development, including linguistics and other academic areas. Translanguaging, which allows students to draw upon their multilingual abilities to comprehend complex concepts while preserving their cultural identities, is shown to be indispensable for academic and social integration. However, the study also highlights the existing hesitancy in formal academic usage of translanguaging, emphasizing the need for educational institutions to reevaluate their approach and embrace multilingualism as a valuable academic resource.

Moreover, the study has revealed that bilingualism contributes significantly to resilience and adaptability among individuals, particularly in overcoming language barriers and thriving in new academic environments. This adaptability not only enhances their academic experiences but also deepens their engagement with their studies. The implications for pedagogy are substantial, with translanguaging pedagogy emerging as a powerful educational strategy that values linguistic diversity and leads to improved learning outcomes. Nonetheless, the study acknowledges the challenges of overcoming institutional resistance, raising educator awareness, and addressing resource constraints in the implementation of translanguaging pedagogy.

The use of translanguaging in a multilingual science classroom can improve students' ability to understand and engage with scientific ideas and language. It also helps students feel more included and able to express their identity [35] Translanguaging pushes back against the unfair tendency in schools to treat monolingualism as superior, which often harms multilingual students [35] This approach supports growth in students' home language and the main classroom language, and academic success in science [35]. By allowing students to fluidly draw on all their linguistic resources, translanguaging enables deeper and more meaningful learning of complex scientific concepts and practices [35].

Furthermore, bilingualism's distinct advantages in STEM fields are evident, providing a vital foundation for understanding complex scientific concepts and effectively communicating with diverse audiences. The cognitive benefits of bilingualism, such as enhanced problem-solving and memory skills, prove particularly valuable in scientific disciplines. Linguistic diversity is identified as a catalyst for innovation in academic settings, especially in scientific fields, introducing diverse perspectives and methodologies. Therefore, the study emphasizes the

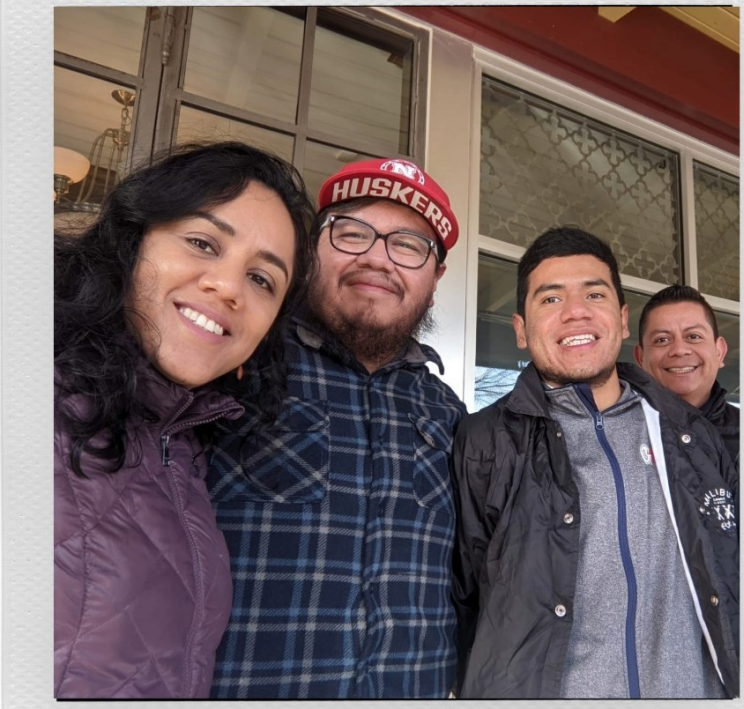
importance of overcoming language barriers and supporting linguistic diversity through language instruction and academic assistance to facilitate scientific progress and address global challenges.

In the context of inclusivity, the study underscores the necessity of valuing linguistic diversity in academic environments. Embracing multiple languages creates a welcoming and inclusive atmosphere that fosters diverse perspectives essential for scientific advancement. To achieve this inclusivity, the study recommends addressing structural barriers and providing resources for bilingual or multilingual instructional materials and language support programs.

Lastly, the study emphasizes the integration of linguistic capabilities into academic programs, particularly in fields like Biosystems Engineering, to bridge the gap between theoretical knowledge and practical application. This integration enhances learning experiences and reinforces the importance of linking theory with practice.

Embracing and supporting translanguaging and bilingualism in education not only benefits individual students but also enriches the entire academic community, aligning with the global and multicultural dimensions of modern education and research. The study calls for a reevaluation of educational practices to fully harness the potential of linguistic diversity and create inclusive, innovative, and resilient learning environments.

The authors



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