Development and Evaluation of Access+Content+Language = STEM (ACL=STEM) Program for Culturally and Linguistically Diverse Youth (Work-in-Progress)

Dr. Betsy Chesnutt, The University of Tennessee, Knoxville

Betsy Chesnutt is a teaching associate professor in Engineering Fundamentals at the University of Tennessee-Knoxville. She is interested in understanding how to prepare pre-service teachers to teach engineering, as well as how to support current K-12 teachers so that they can implement engineering into K-12 classrooms more effectively.

Chulin Chen, The University of Tennessee, Knoxville

Chulin Chen is pursuing his Ph.D. degree in STEM Education at the University of Tennessee, Knoxville. He earned his BS and MS in Industrial and Systems Engineering, and his work focuses on applying systems engineering approaches and computational thinking to broader real-world contexts, with an emphasis on engineering and computing education. He is deeply motivated by the potential of AI, computing, and engineering for social good, particularly in ways that connect technical knowledge with community needs and lived experiences.

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Abstract

In this paper, we describe the development of a community-based after-school engineering program for middle-school-aged culturally and linguistically diverse youth (CLDY). This program was designed to provide CLDYs with opportunities to engage in authentic engineering activities while also supporting their academic language development. Previous research has shown that CLDYs face multiple educational challenges and exhibit significant achievement gaps. Consequently, they are under-represented in science, technology, engineering, and math (STEM) majors and careers. This project seeks to reduce this opportunity gap by providing CLDYs with STEM learning opportunities beyond school, as well as to provide them with opportunities to further develop their academic English proficiency. The overall goal of this work is to contribute to the field of P-12 engineering education research by articulating design principles that make engineering and STEM learning more meaningful, accessible, and engaging for bilingual and multilingual students, particularly in out-of-school informal settings. In this paper, we describe the initial development of the program and the lessons learned from the implementation of a pilot program. Throughout the pilot program, we also collected written work from participants and recorded their verbal interactions with other participants and facilitators. At the end of the pilot program, we utilized a reflective inquiry approach to conduct in-depth interviews with all participants to investigate their ability to articulate their understanding of engineering concepts, the development of their academic language use related to those concepts, and their STEM identity development. Specifically, we focused on investigating how students reflected on their learning of engineering concepts, their use of academic and informal language, and their sense of autonomy and identity as emerging STEM learners. In these interviews, students demonstrated an improving ability to talk about engineering work and persistence with completing hands-on projects. They also indicated that they had come to view engineering as both collaborative and creative. These preliminary findings will be used to inform the design of the next phase of the project, when we plan to expand the program and make it available to more students.

Background and Motivation

Culturally and linguistically diverse youths (CLDYs), including English learners (ELs) and bilingual/multilingual students make up more than 10% of the total K-12 student population in the United States, and the number of CLDYs in K-12 schools is continuing to increase [1]. CLDYs and ELs face multiple educational challenges, and as a result, exhibit significant achievement gaps. ELs are less likely to graduate from high school than non-ELs (73% vs. 89%) and far less likely to pursue higher education

(18% vs. 43%) [2]. This has significant long-term implications, as there is a significant difference in median income between people who did not finish high school ($35,624) and bachelor's degree graduates ($74,464) [3]. These early achievement gaps lead to persistent under-representation in science, technology, engineering, and math (STEM) careers. While Hispanic adults make up 17% of the total U.S. workforce, they only represent 8% of the workforce in STEM and STEM-related occupations [2]. One important contributing factor is the lack of access to STEM-related courses in K-12 settings as well as content that is inaccessible for ELs. One potential way to reduce the accessibility and opportunity gap for CLDYs is to provide them with additional learning opportunities beyond the walls of school classrooms. The goal of the Access+Content+Language = STEM (ACL=STEM) project is to provide ELs with ***Access*** to mentors who are pursuing college degrees in STEM-related fields, ***Content*** specifically designed to integrate STEM concepts with academic English literacy, and an opportunity to practice using academic English ***Language***. This ensures that CLDYs are critically engaged with STEM content while simultaneously developing the necessary academic English that supports their content learning. We chose to implement ACL=STEM at the middle school level because research shows that middle school STEM education determines students' intrinsic interest in STEM and career aspirations [4].

Program Description and Research Methods

The initial implementation cycle encompassed five 90-minute after-school sessions that were held at a local youth-focused community center. Participants engaged in experiential learning activities focused on engineering design. The sessions were led by bilingual undergraduate engineering student mentors. To examine how participants experienced and described their learning, interviews were conducted with four students at the conclusion of the first cycle. Each interview lasted approximately 20 minutes, and the participants were multilingual middle school students (grades 6–7) who self-identified as ELs or recent arrivals to the U.S and who represented diverse linguistic and cultural backgrounds, including East Asian and African language communities. The interview protocol encompassed open-ended inquiries targeting students' initial perceptions of engineering, learning experiences within the program, comprehension of fundamental engineering concepts, utilization of language during problem-solving, and STEM identity. Interviews were audio-recorded, transcribed verbatim, and analyzed using open and axial coding methods to identify themes related to students' conceptual understanding of engineering, use of language to express and explain ideas, and evolving sense of identity as STEM learners [5]. Each transcript was meticulously reviewed on multiple occasions to identify patterns in how students interpreted hands-on activities, navigated challenges, and described their learning experiences.

Theoretical Framework

This study is guided by sociocultural and practice-based perspectives on learning [6,7] that emphasize the centrality of language, identity, and participation in meaning-making activities. We conceptualize learning not merely as the acquisition of abstract concepts, but rather as engagement in cultural and disciplinary practices, mediated by tools, language, and social interaction [8,9]. For bilingual and multilingual learners, content learning is inextricably linked with language development and identity formation [10,11]. In STEM learning environments, the affirmation of students' cultural and linguistic resources has been shown to support more robust academic engagement [12,14]. This affirmation is especially evident when students are provided with opportunities to communicate ideas through dialogue, gestures, metaphor, and code-switching. The project also draws on frameworks of STEM identity development, especially in out-of-school settings. The concept of identity is regarded as a dynamic and interactive process, shaped through participation and recognition within learning environments [14,15]. Prior research suggests that engaging in personally meaningful, community-rooted STEM projects can foster a sense of belonging and competence, particularly for youth from historically marginalized groups [16-18].

Preliminary Results

A thorough analysis of the participant interviews yielded several interconnected themes that illustrate how multilingual youth engaged with engineering concepts, language, and identity during the program. The findings provide preliminary evidence that the program supported both conceptual understanding and STEM identity development through hands-on, collaborative learning in a community-based setting.

Reframing Engineering as Understandable and Doable

A notable shift in perceptions of engineering was observed among all participants. While participants Initially regarded engineering as intimidating or the exclusive domain of "smart" people, at the end of the project, they viewed it as a field that was both attainable and comprehensible. This transition was frequently associated with their experience troubleshooting, completing builds, and observing tangible results. As one student reflected, "*We had the problem with resistors, which affected how my light works*," demonstrating an understanding of electrical components and the underlying cause-and-effect relationships. Another noted, "*Putting them in parallel to the resistor… then they would turn on,*" describing their learning in practical terms.

Using Language, Metaphor, and Multimodal Expression to Make Meaning

The participants employed a variety of rhetorical strategies, including metaphors, gestures, and bilingual discourse, to articulate and make sense of engineering concepts. These meaning-making

strategies seemed to help them bridge abstract concepts using metaphorical analogies, enabling clearer understanding of complex content. These analogies served as cognitive tools that supported their reasoning and conceptual clarity. For instance, one participant shared, "*The light is like a message — it tells you if the code is working*," while another described the Arduino as "*like a brain*." These metaphors demonstrate how students employed figurative language to conceptualize and analyze abstract engineering concepts.

Identity Shifts: Feeling Capable and Curious about STEM

Participants demonstrated sentiments of pride, resilience, and a developing sense of self as STEM learners. These reflections, characterized by their affective and identity-oriented nature, were frequently associated with experiences of challenge and subsequent resolution. One participant claimed, "*When it worked, I felt proud of myself… like solving a puzzle.*" Another commented, "*Computer engineers are people who don't give up… I will try again until I get something right.*" These narratives demonstrate that engagement in this STEM program fostered the development of a STEM identity in participants. These findings suggest that when engineering learning is intentionally designed for CLDYs and situated within supportive, community-based environments that provide necessary language scaffolds, these multilingual youths begin to engage profoundly with STEM content and to see themselves as engineers.

Conclusions

While much of the research on English learners in STEM focuses on classroom-based interventions, this project underscores the potential of out-of-school learning spaces as powerful contexts for supporting both disciplinary understanding and STEM identity development. Community-based environments, when specifically designed just for CLDYs, have the potential to offer multilingual youth valuable opportunities to engage in authentic, hands-on engineering practices. This study contributes to the growing body of scholarship on content-area learning for linguistically diverse students by demonstrating how engineering design challenges, in conjunction with dialogic scaffolding and peer collaboration, can foster both conceptual mastery and heightened self-efficacy among linguistically diverse learners that is not readily available in the public-school settings. These findings emphasize the value of culturally and linguistically sustaining approaches to STEM instruction [12,13]. As the program progresses, future cycles will incorporate findings into expanded curricular tools and professional learning materials for educators working with multilingual youth to strengthen the case for community-based, content-rich STEM programming that affirms multilingual learners' capacities and identities while building a more inclusive foundation for future participation in STEM.

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