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Fostering Belonging, Self-Efficacy, and Persistence in Computer Science: Results from an AISL Bilingual Informal Learning Program

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Fostering Belonging, Self-Efficacy, and Persistence in Computer Science: Results from an NSF-AISL Bilingual Informal Learning Program

For decades, experts and organizations, including the National Science Foundation, have emphasized the importance of focusing on informal learning settings as contexts to broaden participation in computer science (CS) education [1]. Informal education has always been regarded as a fertile ground for growing and developing young minds and cultivating future talent. While rigorous and inclusive informal opportunities are not always available or accessible to many students [2], engaging both the public and youth with STEM fields continues to be critical to raising awareness, fostering interest in future career opportunities, and maintaining U.S. competitiveness in these areas [3].

Program Description

The "Collaborative Research Broadening Participation of Latinx Students in Computer Science by Integrating Culturally Relevant Computational Music Practices" (Remezcla) project, funded by the National Science Foundation's Advancing Informal STEM Learning (AISL) program, was designed to address this challenge and broaden participation in CS among Latino and Spanish-speaking students by teaching them programming through music composition and remixing in EarSketch. Developed through a collaboration between Georgia Institute of Technology and the University of Puerto Rico- Rio Piedras, this initiative is built upon a robust partnership and our collective commitment to increasing opportunities in STEM education. Remezcla involved the implementation of a range of technological, curricular, and research innovations aimed at creating an effective informal learning experience that fostered students' computational thinking and strengthened their sense of belonging, self-efficacy, and intention to persist in CS. These innovations were grounded in deep collaborative relationships among interdisciplinary experts, practitioners from both universities, and educational partners, as well as ongoing and rigorous evaluation processes that informed adaptations and refinements at each stage of the project. Those tightly woven structures and our dynamic approach allowed our research-practice partnership to evolve and ensured it remained impactful, and consistently addressed key educational and implementation challenges [4].

As part of the program's technological innovation, we incorporated multilingual functions into EarSketch, our music remixing platform. Those functions allowed users to access the platform content and existing instructional materials in English and Spanish, and to switch between languages with ease. We also collaborated with artists in Atlanta and Puerto Rico to add Latin music clips to the platform's sound browser, so students could create musical forms related to traditional and modern Latin genres. At the curricular level, we created and assessed bilingual informal CS learning programs in the form of after-school and summer camps for middle and high school students. The curriculum drew on best practices from culturally relevant and sustaining education [5]– [7] and was grounded on principles from

motivational and self-determination theories [8]. These programs were implemented between 2021 and 2024 in Atlanta and Puerto Rico. We also developed Spanish/English attitudinal instruments that measured our constructs of interest using cultural equivalency guidelines [9]. This rigorous and innovative methodology helped ensure that we could accurately measure students' perceptions and the impact of the program, while maintaining semantic and cross-cultural validity in our instruments.

Methods and Procedures

During the pilot year, we established many of the processes and structures that proved crucial to the project's success during our funding period. This included creating interdisciplinary, multi-organization sub-working groups aligned with the expertise and interests of the team members; logistical team structures and workflows at each site focused on location-specific needs; and a cadence that allowed these groups' work to naturally advance the common agenda. Of crucial importance was defining how we would collaborate to accomplish the overall project's goals at both sites, while respecting and uplifting the needs of culturally diverse students and our distinct contexts. Although our work and connections continued to evolve over time, establishing our "sibling programs" based on mutual respect, open communication, collaborative decision-making, and a common vision strengthened by autonomy, was key to creating a strong foundation for success. This was particularly the case for this project, which was made even more complex by the need to develop partnerships and deploy instructional programs at the onset of the COVID-19 pandemic.

Our initial efforts were dedicated to developing the major technical modifications required for EarSketch and translating the platform content and existing instructional materials into Spanish. We also launched the artist collaborations and crafted a vision for the music development aspect of the project. Simultaneously, we established our K–12 school and organization partnerships and created an early draft of our curriculum and research instruments which would be piloted in an online format in the summer of 2021. In subsequent years, we followed similar iterative cycles, marked by continuous and intentional research and evaluation processes to inform changes, adaptations, and decision-making.

During years 2 and 3 our priorities centered on expanding our new music databank, validating users' experiences with the technical enhancements made to EarSketch, and developing and refining our research instruments. To measure our primary constructs of interest and test our theory of change, we developed three bilingual instruments (intake, pre and post surveys) in English and Spanish [9] using a methodology that established semantic, content, technical and conceptual cultural equivalency [10]. Using adapted items from traditional scales previously validated with youth from under-represented backgrounds in the U.S., these surveys captured students' educational and personal information, constructs such as identity identification (Multidimensional Inventory of Black Identity-Teen [11]), perceptions of cultural congruity or threat (Perceived Threat Scale [12], [13]), computer science self-efficacy (Motivated Strategies for Learning Questionnaire [14]), sense of

belonging in CS (Sense of Social and Academic Fit in STEM [15]), intention to persist (The BASICS Study Student Questionnaire Measures [16]), and their perceptions of cultural integration in the curriculum and instruction (Student Measure of Culturally Responsive Teaching [17]).

These instruments were administered to participating students from whom we obtained parental and student consent for each summer and after-school implementation between 2021 and 2024 in Atlanta and Puerto Rico. By the end of the project, we had collected data from 521 participating students, including 265 matched pre- and post-survey cases. Additionally, we gathered qualitative data from students through end-of-program focus groups designed to capture their experiences and gather their feedback. We also conducted cognitive interviews where students reflected on their individual work and shared their thought processes and motivation while creating music and coding with EarSketch. Lastly, we completed interviews with the program instructors to capture their experience with the curriculum, and while teaching both the after-school and summer camps.

During years 4 and 5, we concentrated on improving and enhancing the curriculum and capturing students' growth in content mastery and computational thinking. As previously stated, the curriculum was built using principles of culturally responsive and sustainable learning, as well as asset-based pedagogy. Early iterations featured scaffolded lessons that encouraged students to find inspiration for their musical creations on personal, familiar, social and community themes, progressing from more immediate to broader contexts in alignment with Bronfenbrenner's ecological systems framework [18]. However, students tended to focus more on the musical and aesthetic characteristics of their final songs and products, rather than the computational functions or processes they used. Recognizing this challenge, we sought ways to motivate students' engagement with more advanced computational concepts and tasks, without sacrificing the informal nature of the experience or students' expectations for the learning environment. This was also critical for program retention as students emerged from the pandemic exhausted by screens. As a result, we redesigned the curriculum into mastery-driven challenges including increasingly complex computational requirements and paired them with a badging strategy that capitalized on extrinsic rewards and explicit social and peer-recognition activities [19]. We also measured students' content knowledge by analyzing their programming scripts using a code complexity tool [20] and, based on Brennan and Resnick's framework [21], establishing and comparing the level of complexity of the programming functions they used and their aligned computational thinking concepts.

Results

Our research findings span multiple papers and specific studies, both published and in progress. Overall, our research suggests that the Remezcla program was an effective intervention, increasing students' pre–post sense of belonging and self-efficacy in computer science. Summer camp programs, in particular, showed the most promise as an intensive and

effective intervention setting [22]. While our analysis shows that prior knowledge might play a prominent role in predicting these outcomes, we are currently examining gender, identity, and location-specific results that highlight the complex nature of these interventions, especially in domains such as computer science [23].

Comparative analyses of our curricular iterations also indicate that the Challenges and Badging strategy changes made to the curriculum after 2022 led students to use more advanced forms of programming more frequently, with corresponding statistically significant increases in sense of belonging and CS self-efficacy compared to previous years [19]. However, further research is needed to explore students' intention to persist and its interplay with youth and identity development during middle and high school. Specifically, we need to examine how persistence manifests in various forms at different developmental stages, and its relationship with students' interests and their future career and personal goals.

Qualitatively, students have reported profound experiences of belonging, cultural and linguistic affirmation, empowerment and liberation that helped them envision possibilities and paths not previously considered [24]. Those findings underscore our expectation that asset-based pedagogical learning environments that honor students' whole selves, including their culture and language, continue to be critically important for youth belonging and well-being. Further, some of these findings emerged in online programs, demonstrating that these rich learning experiences can also be created in virtual spaces.

Lastly, through our cross-cultural and multilingual validation process, we showed that it is possible to create instruments capable of measuring complex, developmentally dependent socio-motivational constructs among middle and high school Latino/a/e students across different cultures and contexts. We are hopeful that our measures (being prepared for publication) can be used by researchers and practitioners in the future.

Although our project began with the goal of broadening participation among Latino/a/e and Spanish-speaking students in the U.S., it serves as a testament to how thinking expansively can create unknown opportunities and open unexpected doors. Between 2023 and 2025, EarSketch was accessed in Spanish by over 5000 users, including more than 3000 users in the continental U.S., followed by Spain (>500), Mexico (>500), Puerto Rico (>400), Argentina (>300), Canada (>300), and Guatemala (>200), significantly expanding the platform's footprint to other Spanish-speaking countries globally. Soon after launching the multilingual function, opportunities for growth became evident. EarSketch currently supports nine languages, including English, Spanish, French, German, Hebrew, Arabic, Ojibwe, Inuktitut, and Uzbek, while remaining an accessible, free and online platform. The final bilingual curriculum and its associated instructional materials are also available to educators and the public, creating possibilities for use in diverse informal learning settings by students across the U.S., Puerto Rico, and beyond. While much of today's conversation around computer science is dominated by the perceived need to learn and teach about AI, programs like ours focus on the foundational computational thinking skills that young people will need for any

career that involves digital technology and computing. By emphasizing informal learning environments and adapting to a variety of educational and cultural contexts, Remezcla illustrates how computer science education can thrive both within and across communities. Towards the end of this project, many of our team members felt equally transformed by the community we built among ourselves, our partners, our students and their families. The principles we used to create this project built a home for everyone. To bring your whole self, as a learner and a person, and to be given the opportunity to explore new and exciting worlds with passion and freedom so you can grow within yourself and with the world – that is the promise of education for us all.

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