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Beyond "fitMedia Forever": Assessing Student's CT Competencies and Learning in an Informal CS Program

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Beyond 'fitMedia Forever': Assessing Student's Computational Competencies and Learning in an Informal CS Program

Access to high quality computer science (CS) education is essential for developing 21st century skills critical to information technology and computing careers. Yet only 60% of over 24,000 U.S. public high schools offer a foundational CS course, with students from historically underrepresented groups being less likely to enroll them [1]. Namely, Latino students make up 29% of U.S. high schoolers, but only 21% take foundational CS courses [2]. Informal learning (IL) programs can expand access to CS but often fail to adequately address the needs of underserved students [3] or employ asset-based pedagogies that foster engagement and participation while valuing students' unique knowledge and experiences. Broadening participation to Latino youth in CS requires addressing the multicultural and linguistic diversity that exists within and across students, mitigating the negative impact of stereotype threat and uncertainty belonging prevalent in STEM [4],[5], and integrating cultural knowledge and asset-based principles into curricula and instructional practices [6]. The current study was conducted within the context of an NSF Advancing Informal Science Learning (AISL) funded program. This collaborative project, colloquially referred as Remezcla, between Georgia Tech and the University of Puerto Rico, Rio Piedras (UPR), was created to engage Latino youth in CS by integrating culturally and linguistically affirming practices and innovations into informal learning experiences. The project uses EarSketch, a free web-based platform designed to teach core concepts in CS [7] and engage students in programming through music creation [8]. As part of Remezcla, EarSketch was transformed into a multilingual platform, made available in Spanish, and added 900+ Latin-inspired music clips and beats to its library of more than 5000 sounds. Similarly, informal afterschool and summer programs were developed that connected CS with students' interests and lived experiences [9],[10]. This paper explores the impact of the Remezcla bilingual, culturally relevant and asset-based intervention by comparing the effectiveness of two curricular iterations that incorporate different motivational strategies, on students' CS content knowledge and attitudes towards computing.

Theoretical framework

The Remezcla curriculum was designed to reflect best practices from the Culturally Relevant Education Framework [11], which incorporates aspects of culturally responsive teaching [12] culturally relevant pedagogy [13], and culturally sustaining pedagogy [14]. Preliminary studies using pre-post data suggest the Remezcla program significantly impacts students' belonging and self-efficacy [15]. Youth also describe being inspired, engaged, accepted, and experiencing psychological and emotional well-being while participating in the program [16]. While these studies were conducted considering the effectiveness of the overall intervention, we were interested in understanding more directly what program components could motivate students to use higher level computational skills.

Computational thinking (CT) literature includes multiple definitions and frameworks that propose developmental, skills and learning progressions [17]. Brennan and Resnick's framework [18], which was developed for assessing knowledge associated with using Scratch, includes three dimensions in its CT definition: CT concepts (concepts used while programming), computational practices (practices developed while programming), and computational perspectives (understandings formed of the world and of oneself). EarSketch already creates a highly engaging environment by melding students' creative thinking into the programming process. However, results from prior EarSketch research and our own pilot studies suggest that students' motivation towards creating more aesthetic musical products can run counter to having them use more complex forms of programming like variables and loops and instead rely heavily on repeated sequential calls of simpler functions like “fitMedia(),” which add sound clips to the student digital workspace. Our team has coined this phenomenon as “fitMedia forever.”

To address this problem, our program introduced a major change between the first and second curricular iterations. Specifically, the second iteration of the curriculum incorporated a mastery-driven challenge and badging strategy that leveraged extrinsic rewards [19] and principles of gamification [20] to maintain students’ engagement and complement mastery and culturally affirming experiences. Guided by self-determination theory [21], [22], we posited that reframing the curriculum activities as a set of music creation/coding challenges which students could complete to earn badges, could propel them to engage with a variety of EarSketch functions and computing concepts, and push them to engage in higher levels of mastery of CS skills, while supporting their curiosity, creative autonomy, competence and belonging.

This paper explores the effect of a mastery-driven challenge and badging strategy on students’ learning and motivational outcomes. Specifically, we examine the extent to which participating students incorporated computing concepts into their projects, reported increased self-efficacy and a sense of belonging in CS, and whether notable differences emerged in these outcomes before and after the implementation of the challenge/badging approach.

Research design

The Remezcla curriculum [23] encourages youth to connect their interests and culture by creating music through CS programming. The program integrates culturally relevant, youth-centered activities aligned with the K-12 Computer Science Framework [24] and the Kapor Center’s culturally responsive-sustaining framework’s core components [25]. The first iteration (Iteration 1) of the curriculum implemented during 2021 and 2022 consisted of scaffolded units thematically focused on student’s personal, family/friends, school/summer and broader community dimensions. They included capstone challenges such as *Self Portrait* where students created a 30 to 40 second musical self-portrait by applying concepts learned in prior lessons. In the second iteration (Iteration 2) of the curricula, which was implemented between 2022 and 2024, all activities and lessons were re-structured and reframed as part of specific musical and programming challenges that also reflected student’s interests and cultures. For example, in the *Storyteller/Cuenta Cuentos Challenge,* students were invited to tell a family or community story through the creation of a full song that was organized by sections using custom functions, transitions, and looped beats. As part of these challenges, students earned badges in the form of pinback buttons or stickers, by meeting programming milestones. After each challenge, instructors publicly celebrated students as they received badges, recognizing and validating their computational competence, having them share their music with their peers, and fostering a community of mutual celebration (See Table 1 for a sample of the challenge and badging strategy employed during the 2024 summer programs).
To ensure we were moving students along a CS mastery continuum, we mapped all the program challenges and coding functions used in EarSketch to CT concepts (sequences, loops, conditionals, operators, and data) [26]. Student code was further categorized into three programming levels (linear, linear plus variables, and modular) as follows:

Linear programming challenges: Introduce students to fitMedia(), a function that adds sound clips to a timeline, helping them explore function calls, parameter settings, and sequencing. Novice programmers learn proper syntax, capitalization, and script conventions while gaining familiarity with the EarSketch environment, musical time, and how function calls determine the order and duration of sound samples.

Linear programming with variables: Expand linear programming by introducing variables, tempo settings, and commenting. Students define sound variables (i.e. piano), explore genres by changing tempos, and ensure data types (integer, character, etc.) match makeBeat() function requirements for creating original beats.

Modular programming challenges: Introduce modular programming with for loops to repeat the call of the makeBeat() function and use adaptable beat string variables. Conditionals validate readInput() data, ensuring it meets setTempo() bounds, with Boolean operators defining limits.

TABLE I
SAMPLE OF ITERATION 2 (CHALLENGES AND BADGING) ACTIVITIES IMPLEMENTED DURING SUMMER 2024

Challenge/Badge: First Project/ Primera Canción	
Description	Create a 3-4 track musical introduction
Musical Topic(s)	Measure; Tempo
Criteria	fitMedia; setTempo
CT Concepts	Sequences
K-12 CS Framework Standards	Algorithms and Programming
Culturally Responsive Components	Validate student voice/agency (CC-04)
Challenge/Badge: DJ Challenge	
Description	Create (or modify) a rhythm
Musical Topic(s)	Rhythm; Beat; Genre
Criteria	Variables; makeBeat
CT Concepts	Sequences; Data
K-12 CS Framework Standards	Variables
Culturally Responsive Components	Validate student voice/agency (CC-04); Include families/community (CC-05)
Challenge/Badge: Master DJ	
Description	Loop the rhythm computationally
Musical Topic(s)	Adding repetition
Criteria	Variables; Multiple makeBeats; for loops
CT Concepts	Sequences; Data; Loops
K-12 CS Framework Standards	Control
Culturally Responsive Components	Validate student voice/agency (CC-04)
Challenge/Badge: One Latin America Challenge/ Canción Final	

Description	Create a song inspired by your culture, personality, and/ or interests
Musical Topic(s)	Musical Expression
Criteria	Students select elements to include
CT Concepts	Will vary based on student's individualized projects
K-12 CS Framework Standards	Will vary based on student's individualized projects
Culturally Responsive Components	Build inclusive classrooms (CC-02); Validate student voice/agency (CC-04)

Data collection and analysis

Remezcla afterschool and summer camp programs took place in Metropolitan Atlanta, Georgia and Northeast Puerto Rico. Due to COVID-19, UPR's instruction was fully virtual in 2021-22, while Atlanta's was virtual only in the fall of 2021. In 2022, UPR's afterschool shifted from a school-based format to a central hub hosting students from multiple schools. Summer camps ran concurrently at both locations, with middle schoolers attending the first week and high schoolers the second. Atlanta's camps were always in person at Georgia Tech, while Puerto Rico hosted a virtual camp in 2022 and in-person camps at the UPR campus in 2023 and 2024. Atlanta recruited students through partner schools, whereas Puerto Rico used open enrollment, drawing participants from across San Juan and beyond. Programs at both sites covered similar content with site-specific adaptations. Each implementation covered functions and concepts such as, fitMedia( ), setEffect(), variables, makeBeat(), and for Loops. Conditionals were taught in Atlanta in three implementations of Iteration 2 and during one implementation in Puerto Rico. ReadInput/print was taught in both Atlanta and Puerto Rico during both implementations of Iteration 1.

Participants included 534 students who attended the 2021-2024 Remezcla programs and agreed to be part of the research study. They were invited to complete three survey instruments (pre, post, and an intake survey which captured demographic and background information) that were validated using a culturally equivalent methodology [27], [28]. Students were invited to take the survey electronically in their language of choice (English or Spanish). Intake and pre survey were administered before instruction began and the post-survey on the last day of the program. Students also shared electronically their EarSketch code for each assignment for later analysis. The afterschool and summer programs conducted between 2021 and 2022 implemented the first iteration of the curriculum and included 178 students (44% girls and 49% boys, with 3% preferring not to answer). Youth participating in the second iteration of the program (Challenges and Badging) enrolled between fall 2022 and summer 2024 and included 356 students (36% girls and 60% boys, with 2% preferring not to answer). Additional information about the participants is included in Table II.

TABLE II
Remezcla PARTICIPANT DEMOGRAPHICS BY PERCENTAGE

		Iteration 1	Iteration 2
Gender	Girls	44	37

	Boys	49	60
	Not listed	0	1
	Prefer not to say	3	2
	Missing	4	1
Race/Ethnicity	Latin/Hispanic	24	23
	Puerto Rican/Boricua	57	55
	Mexican/Mexican American	12	12
	Other Central American/Caribbean	5	5
	It is not included in this list	2	4
	Missing	0	1
Grades	6-8	31	37
	9-12	64	62
	Missing	5	1

Participants were asked about their demographic information, prior CS experience, and music interest. The pre and post survey instruments included a variety of socio-emotional scales, including our two constructs of interest in this paper. Sense of belongingness in CS was measured using a six-item scale adapted for computing from the *Sense of Social and Academic Fit* instrument [29] that explored how students felt valued, respected, and included. Self-efficacy was investigated using nine items adapted from the *Motivated Strategies for Learning Questionnaire* [30] that captured students' beliefs in their abilities to accomplish tasks related to computing [31]. In addition, we assessed students' learning by analyzing students' EarSketch code for each challenge, in alignment with National Resource Council recommendations that assessments reflect the engaging aspects of out of school programs [32].

Student code was analyzed using a code complexity tool [33] that examined the abstract syntax tree (AST) of EarSketch scripts. The analysis is based on a CS taxonomy that categorized 15 computational concepts across four knowledge categories, including value types, data storage, operations, and procedures. The tool was used to analyze the progression of complexity of computing and musical concepts over the entire version history of a student's EarSketch project. These code complexity analyses allow us to determine the existing alignment between the CS content and skills demonstrated by students in response to specific challenges. Specifically, scripts were categorized based on three conditions: evidence of linear programming, using fitMedia() only, which indicated novice computing knowledge; the use of variables, which would indicate higher levels of mastery; and evidence of modular coding as demonstrated by the use of loops and conditionals. In all cases, we only attended to scripts associated with challenges that either required the use of those specific functions for completion, or that were submitted after that specific content had been covered in the program. Sense of belonging and self-efficacy pre- and post-scores were analyzed using paired sample t-tests. To examine differences between groups, Welch's ANOVA was conducted, followed by Games-Howell post hoc analyses.

Results

Findings revealed that during the Challenges and Badging implementation more students incorporated higher amounts of modular coding, with fewer students relying solely on fitMedia(), compared to those who participated in the program during the first iteration of the curriculum (see Tables III, IV, and V).

Linear programming. Scripts that incorporated fitMedia() only met the requirements for the linear programming category. During Iteration 1, over 58% of all scripts submitted relied solely on fitMedia(), compared to 20% of scripts during Iteration 2.

TABLE III
LINEAR PROGRAMMING

Iteration 1 (2021-2022)				
	n Participants	*n* Scripts Submitted	*n* Scripts using fitMedia() only	% Scripts using fitMedia() only
Afterschool Program	36	84	44	52%
Summer Camp	71	116	72	62%
Total	107	200	116	58%
Iteration 2- Challenges & Badging (Fall 2022-2024)				
	n Participants	*n* Scripts Submitted	*n* Scripts using fitMedia() only	% Scripts using fitMedia() only
Afterschool Program	109	317	53	17%
Summer Camp	174	518	117	23%
Total	283	835	170	20%

Use of variables. Scripts that incorporated variable functions represented scripts from both the linear programming with variables and modular programming levels. During Iteration 1, 71% of all scripts (79% from the afterschool program and 66% from the summer program) incorporated variables. During Iteration 2, 70% of scripts submitted during the afterschool program and 78% of scripts submitted during summer camps incorporated variables, for a total of 75% of all scripts.

TABLE IV
USE OF VARIABLES

Iteration 1 (2021-2022)				
	n Participants	*n* Scripts submitted	*n* Scripts using variables	% Scripts using variables
Afterschool Program	36	34	27	79%
Summer Camp	54	68	45	66%
Total	90	102	72	71%
Iteration 2- Challenges & Badging (Fall 2022-2024)				
	n Participants	*n* Scripts submitted	*n* Scripts using variables	% Scripts using variables

Afterschool Program	109	290	204	70%
Summer Camp	174	514	400	78%
Total	283	804	604	75%

Modular coding. Evidence of modular coding was evaluated based on the presence of loops, conditionals and operators in students' scripts. During Iteration 1, 42% of qualifying afterschool scripts and 16% of summer camp scripts included modular coding. During Iteration 2, this increased to 61% (after school) and 71% (summer camps). Overall, we see an increase of 44% in the use of modular programming (from 23% to 67%) before and after the Challenge and Badging implementation. Additionally, 16 summer camp scripts (not included in this table) incorporated modular coding in earlier challenges despite not being required by the curriculum.

TABLE V
MODULAR CODING

Iteration 1 (2021-2022)				
	n Participants	*n* Scripts submitted	*n* Scripts using modular coding	% Scripts using modular coding
Afterschool Program	36	26	12	42%
Summer Camp	54	68	11	16%
Total	90	94	22	23%
Iteration 2- Challenges & Badging (Fall 2022-2024)				
	n Participants	*n* Scripts submitted	*n* Scripts using modular coding	% Scripts using modular coding
Afterschool Program	109	197	120	61%
Summer Camp	174	288	204	71%
Total	262	534	358	67%

An analysis of all Remezcla participants' pre-post results, across all programs indicated that, overall, students reported statistically significant higher levels of sense of belonging *(M1=3.44, M2=3.69; p< .000**, ds = .37)* and self-efficacy *(M1=3.77, M2=3.90; p<.000**, ds = .20)* as a result of their participation. These composite scores were calculated based on participants' responses to the items included in the sense of belonging (6 items) and self-efficacy (9 items) scales. However, a separate analysis of both constructs comparing the attitudes of students who participated in the program before and after implementing the Challenges and Badging curriculum reveals that while there was an increase in pre-post differences in sense of belonging and self-efficacy, these were non-significant during Iteration 1 of the program. In contrast, students who participated in the program after the implementation of the Challenges and Badging curricula (Iteration 2) saw statistically significant increases in both sense of belonging and self-efficacy (See Table VI). Post hoc analyses of both scales' items for Iteration 2 shows that for sense of belonging, students' scores for the item "*I feel comfortable in computing/ Me siento cómodo en la computación*" were significantly greater. *(M1=3.69, M2=3.98; p<.000**, ds =.33)*. In the case of self-efficacy, students who participated in the second iteration of the program were significantly more likely to believe that they expected to do well in computing *(M1= 3.80, M2=3.98; p<.006**., ds =.20)*, receive a good grade in computing *(M1=3.92, M2=4.05; p<.03*, ds =.16)*, that their study skills in computing were excellent compared to others *(M1=3.15, M2=3.48; p<.000**, ds =.36)*, that they could understand the ideas taught in computing classes or activities *(M1=3.95, M2=4.12; p<.005**, ds =.21)*, and that they knew a great deal about computing *(M1=3.06, M2=3.45; p<.000**, ds =.39)*. These, and all self-efficacy and sense of belonging individual item results are included in the Appendix.

TABLE VI
ATTITUDES AND BELIEFS IN COMPUTER SCIENCE BY ITERATION

	Sense of Belonging				
Iteration	*n*	Mpre	Mpost	*p*	*d*
1	86	3.55	3.68	.097	.18
2	235	3.46	3.71	<.001**	.37
	Self-Efficacy				
Iteration	*n*	Mpre	Mpost	*p*	*d*
1	87	3.86	3.86	.991	.001
2	234	3.77	3.92	<.001**	.258

Discussion

This paper explores the effect of a mastery-driven challenge and badging strategy on the computer science learning and attitudes of youth participating in the Remezcla program. The use of computing concepts and functions, as well as pre-post perceptions of sense of belonging and self-efficacy were compared between students who participated in the program before and after the implementation of the Challenges and Badging curriculum.

An analysis of students' programming scripts created during the program shows that students who participated in Remezcla gained a variety of CS content knowledge and learned programming skills that spanned from novice to higher levels of complexity. Youth's scripts from the first iteration of the program (2021-2022) showed high reliance on fitMedia() and minimal use of modular coding concepts. Most of the scripts submitted by students in this period employed linear programming (58%), with only 23% of the scripts including some form of modular programming. In contrast, student scripts submitted after the Challenges and Badging implementation showed an increased use of more complex programming concepts and functions. The use of linear programming decreased from 58% to 20%, while the use of modular programming increased from 23% to 67%. The percentage of scripts that included variables however was high overall and more balanced across iterations. Seventy-one percent of scripts in the first iteration and 75% of scripts in the second iteration incorporated variables.

An investigation of motivational outcomes revealed that, overall, youth reported higher levels of sense of belonging and self-efficacy after participating in the program. This would suggest that the critical components of this culturally relevant and sustaining curriculum supported student competence in CS learning and fostered a positive connection to computer science as a field. However, a comparison of findings between students who participated in the program before and after the Challenge and Badging curriculum, showed that these gains were statistically significant only for those students who were exposed to the second iteration of the curriculum. This indicates that the Challenges and Badging, as designed, strengthened students' confidence and belonging in CS.

Taken together, our study provides evidence that the mastery-driven Challenges and Badging strategy implemented during the second iteration of the Remezcla curriculum positively impacted student learning and motivational outcomes. Students increased incorporation of modular programming and reduced reliance on fitMedia() supports our hypothesis that using a mastery-based challenge and adding badging as an additional incentive were likely to push students to explore various and more complex functions in the program. The statistically significant increases in belonging and self-efficacy also corroborate our belief that by focusing on these mastery challenges in the context of creative tasks and a culturally affirming environment, those learning gains could be accomplished without undermining competence and belonging. Students in the program not only celebrated each other's achievements but they also proudly displayed their earned badges on name tag lanyards and water bottles, reinforcing their sense of accomplishment. This study contributes to the literature on race-reimagined educational psychology [34], [35] by providing insights on how culturally relevant and sustaining programs can support the psychological needs of autonomy, competence and relatedness of Latino students despite the use of extrinsic contingent rewards in high-threat environments like STEM.

These study results should be interpreted with caution. While the Challenges and Badging Strategy encouraged students to engage in more advanced coding, results may also reflect an increase in instructor familiarity with the curriculum, competency and other aspects of the program's design (i.e. ability to provide students with critical feedback). Also, while badging may explain some of the difference, the number of students who participated in the second iteration was higher, which creates an unbalanced sample size between the "before" and "after" groups. In addition, those who participated before the implementation of badging reported higher pre-sense of belonging and pre-self-efficacy than those who participated after the implementation of the curricular changes. Other limitations include incomplete or absent script submissions, attrition in the afterschool program due to transportation issues and mandatory attendance in other programs, and the possibility that the increase in modular programming was driven primarily by the curriculum change and not as much from the badging and celebrations.

To further investigate these findings, we plan to triangulate these data with other qualitative and quantitative data sources. In particular, we are interested in exploring students' perceptions of the impact of the challenges and badges in their learning and motivation through focus groups. We also intend to examine differences in student use of computing concepts and attitudes towards CS based on their prior CS experience and how their engagement and concept use was driven by their programming and creative intentions.

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APPENDIX

TABLE I
ATTITUDES AND BELIEFS IN COMPUTER SCIENCE BY ITERATION (ITEMS)

Sense of Belonging						
Item	Iteration	n	Mpre	Mpost	p	d
I belong in computing	1	86	3.51	3.53	.833	.02
	2	235	3.48	3.40	.154	.09
I feel comfortable in computing	1	86	3.92	3.93	.911	.01
	2	232	3.69	3.98	<.001***	.33
I fit in well in computing at my school	1	86	3.48	3.56	.531	.08
	2	234	3.44	3.71	<.001***	.28
Compared with most other students at my school, I am similar to the kind of people who succeed in computing	1	85	3.35	3.44	.506	.08
	2	235	3.25	3.50	<.001***	.25
Compared with most other students, I know how to do well in computing	1	85	3.40	3.76	.002**	.41
	2	235	3.25	3.74	<.001***	.50
Compared with most other students, I get along well with people in computing	1	86	3.63	3.90	.012*	.34
	2	235	3.65	3.95	<.001***	.34
Self-Efficacy						
Item	Iteration	n	Mpre	Mpost	p	d
Compared with other students, I expect to do well in computing	1	87	3.90	3.95	.607	.07
	2	234	3.80	3.98	.006**	.20
I am certain I can understand the ideas taught in computing classes or activities	1	87	4.13	4.08	.63	.06
	2	234	3.95	4.12	.005**	.21
I expect to do very well in computing classes or activities	1	86	4.05	3.97	.471	.09
	2	233	4.10	4.08	.776	.02
Compared with other computing students, I think I'm a good student	1	87	3.71	3.86	.134	.18
	2	231	3.71	3.85	.014*	.16
I am sure I can do an excellent job on the problems and tasks assigned in computing classes or activities	1	87	3.97	3.94	.818	.03
	2	234	3.91	3.97	.355	.07
I think I will receive a good grade in computing classes	1	85	4.07	3.99	.461	.10
	2	228	3.92	4.05	.033*	.16
Compared with others, my study skills in computing are excellent	1	86	3.31	3.37	.67	.06
	2	233	3.15	3.48	<.001***	.36
Compared with other students, I think I know a great deal about computing	1	87	3.22	3.36	.33	.134
	2	234	3.07	3.45	<.001***	.39
I know that I will be able to learn the material for this program	1	86	4.36	4.17	.055	.261
	2	234	4.29	4.26	.604	.04