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Asset-based Approaches to Multilingual Students' Computer Science Identity Development

RESEARCH

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ABSTRACT

While computer science identity development has been examined in several studies, there is much to learn about the development of multilingual students' computer science (CS) identities. To develop strong CS identities, multilingual students must engage in culturally and linguistically sustaining curriculum, pedagogy, and interaction that draws from their rich and varied resources. This theoretical paper is grounded in a justice-centered, asset-based framework that views the traditions and practices in students' cultures and communities as strong contributors to knowledge construction in STEM. We draw on multiple studies exploring multilingual student CS identity development to better understand how their personal, familial, community-based, and intersectional experiences can be leveraged to promote equitable CS participation. Based on a synthesis of these studies, we find that educators should engage in the following practices: 1) leveraging multilingual students' multiple meaning-making resources, 2) connecting classroom learning to informal learning spaces, 3) providing broader contexts for disciplinary practices, 4) offering multiple opportunities for self-expression, and 5) drawing on multilingual students' strong intersectional identities. Through these practices, we discuss how researchers, practitioners, and policymakers can strengthen multilingual students' disciplinary identification and overall persistence in CS.

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INTRODUCTION

Nurturing computer science (CS) identities is critical to providing culturally sustaining computer science education. When students view themselves as capable participants in CS communities, there are greater possibilities for learning. To this end, learning opportunities are more just and equitable when students can make multiple points of connection between CS and their lived experiences (Jacob, Montoya, et al., 2022; Kapor Center, 2021). culturally sustaining computer science instruction legitimizes minoritized communities' ways of knowing (Nasir & Vakil, 2017). This empowers marginalized students to reimagine disciplinary practices and act as community change agents (Calabrese Barton et al., 2021; Kapor Center, 2021). Research indicates that culturally sustaining computing has several affordances, including increasing student investment in learning, bolstering student interest, and positively impacting self-concept (Byrd, 2016; Hill, 2009; Howard, 2001).

Furthermore, the development of CS identities has shown to be important as early as elementary school, leading to greater interest in the field (Jacob, Montoya, et al., 2022). Unfortunately, credentialing systems nationwide lack multiple subject authorizations for elementary-level CS. Therefore, generalist elementary teachers receive little to no state-sanctioned professional development on how to teach CS to their students (Yadav et al., 2017). While there are a host of CS supplementary authorization programs, these are typically targeted at high school teachers and are not available at the elementary level. Despite the lack of qualified teachers, research indicates that multilingual students benefit from early exposure to CS, beginning in elementary grades (Jacob, Montoya et al., 2022). Findings such as these make providing culturally sustaining CS instruction and professional development a policy issue that school partners and key stakeholders at the district, county, state, and national levels need to consider as they work together to provide culturally sustaining CS education for diverse students.

This is especially important as research shows that students lose interest in STEM as early as middle school, especially when it is unrelated to their lives (Duschl et al., 2007). Programs targeting young learners are critical in CS, in which knowledge, skills, and attitudes are frequently tied to what students learn outside the classroom during elementary and middle grades (Gee, 2008; Bers, et al., 2021; Sullivan & Bers, 2019). Simply put, high-SES students are gaining CS experience through robotics clubs, coding summer camps, and at-home mentoring and modeling to which underserved students have less access (Barron et al., 2009); this leads to gaps in CS knowledge, skills, and attitudes by high school that are difficult to overcome (Wang et al., 2016). Because this trend continues through high school, postsecondary education, and careers, students from historically marginalized communities remain alarmingly underrepresented in the field (US Census Bureau, 2021; Bureau of Labor Statistics [BLS], 2021).

To address this issue, researchers have examined computer science identity development for underrepresented students in several studies (DiSalvo et al., 2011; Rodriguez & Lehman, 2017; Ryoo et al., 2020), yet there is much to learn about the development of multilingual students' computer science identities. Multilingual students face perpetual and systemic inequities in computer science education. For example, educators often exclude students designated as English learners from computer science education opportunities due to the unwarranted belief that they must develop language proficiency before engaging in CS. Furthermore, students designated as English learners are provided unequal access to CS education and careers (Code.org Advocacy Coalition, 2020; Martin et al., 2015). The majority of students designated as English learners in the educational system are Latine. This group is alarmingly underrepresented in computer science (National Center for Science and Engineering Statistics [NCSES], 2021). There is evidence that English learners among Latines suffer the greatest barriers to achievement and technology access (Irwin et al., 2021). These systemic forms of marginalization prevent equitable participation for these students.

To exacerbate these issues, students from underrepresented groups rarely see people who look like them working in CS fields (or play-acting these jobs on TV), and fewer have access to home computers or computer-knowledgeable guardians (Royal & Swift, 2016). This relative absence of media representation and familiar role models has detrimental effects on student interest in the field. Finally, few instructional materials used to teach computer science in K-12 are specifically tailored to the values of students from diverse communities (Goode, 2008; Goode et al., 2018).

To develop strong CS identities, multilingual students must engage in culturally and linguistically sustaining curriculum, pedagogy, and interaction that draws from their rich and varied resources. This theoretical paper is grounded in a justice-centered, asset-based framework that views the traditions and practices in students' cultures and communities as vital contributors to knowledge construction in STEM (Calabrese Barton et al., 2021). Asset-based approaches to computer science education mobilize multilingual students' backgrounds and existing resources to bridge the divide between formal and informal learning environments. This paper discusses how culturally and

linguistically sustaining computing pedagogies lead to more equitable participation for multilingual students. We draw on multiple studies exploring multilingual student CS identity development to better understand how their personal, familial, community-based, and intersectional experiences (or the ways in which issues of race, gender, class, language, and sexuality shape lived experiences; Nash, (2008) can be leveraged to promote equitable CS participation. Based on a synthesis of these studies, we find that educators should engage in the following practices: 1) leveraging multilingual students' multiple meaning-making resources, 2) connecting classroom learning to informal learning spaces, 3) providing broader contexts for disciplinary practices, 4) offering multiple opportunities for self-expression, and 5) drawing on multilingual students' strong intersectional identities (Author et al., n.d., n.d., n.d., n.d.). Through these practices, we discuss how researchers, practitioners, and policymakers can strengthen multilingual students' disciplinary identification and overall persistence in CS.

REVIEW OF THE LITERATURE

Several factors contribute to multilingual students' CS identity development. In this paper, we focus on how culturally and linguistically responsive CS pedagogies foster positive identity formation in multilingual students. We further discuss how these pedagogies present challenges and opportunities for these students' CS learning and identity development.

CULTURALLY SUSTAINING COMPUTING

Funds of knowledge represent the cultural resources that students bring to formal learning environments (Eisenhart & Edwards, 2004). Drawing on funds of knowledge is based on the premise that students' cultural backgrounds are not barriers to overcome but repositories of knowledge acquired out of school that can be leveraged to facilitate the development of formal learning (e.g., González et al., 2006; Moje et al., 2004). Computer science instruction that draws on students' funds of knowledge supports multilingual student identity development by promoting interest in CS, changing negative beliefs about CS ability, fostering persistence in the face of challenges, and facilitating self-expression (Author et al., n.d.).

Culturally diverse students lose interest in science early on when instructional materials are unrelated to their lives and communities (Duschl et al., 2007). Drawing on funds of knowledge makes instruction more relevant to these students and positively shapes their attitudes and interests. Multiple studies suggest that bridging the gap between home and formal learning environments helps students to identify with computing curricula and, ultimately, the field of computer science (Jacob, Montoya, et al., 2022; Jacob, Montoya, & Warschauer, 2022; Vogel et al., 2020). For example, in a mixed-methods paper, Jacob, Montoya, et al. (2022) found that Latine and multilingual students who participated in a culturally and linguistically sustaining CS curriculum shared and projects created in Scratch, a media rich visual programming language for novice coders (Resnick et al., 2009) not only with their immediate families but also with their extended families, peers, and members of their communities. In so doing, they were able to position themselves as experts within their familial and social spheres while spending additional time learning computer science. These opportunities helped to shape students' perceptions of themselves as competent members of CS communities (Jacob, Montoya et al., 2022).

Connecting students' cultural resources to disciplinary content improves school-based outcomes for marginalized students (Lynch & Macbeth, 1998; O'Connor et al., 1998). Cultural resources encompass the accumulated bodies of knowledge that exist in students' households. For example, e-textiles leverage the mathematical and computing principles present in the crafting practices of indigenous and Latine families. Students create wearable technologies by blending crafting rules with circuitry and conductivity to solve local and global problems. Research indicates that multilingual students especially benefit from curricula that integrate e-textiles as they have multiple opportunities to leverage the knowledge of their family members, collaborate with their peers, personalize their projects, and draw upon their conceptual resources as they practice CS (Howell et al., 2016). In characterizing how to draw from students' cultural resources, González et al. (2006) recommend that teachers as ethnographers learn about the sense-making strategies students utilize to navigate their everyday lives (as cited in Eisenhart & Edwards, 2004). Teachers then leverage students' existing strategies to enhance learning.

LINGUISTICALLY RESPONSIVE COMPUTING

Several asset-based approaches to language teaching leverage multilingual students' linguistic resources in service of learning (Grapin et al., 2022; Lee, 2001, 2021). Linguistic resources are defined as the discursive practices present in linguistic communities, such as the presence of irony, satire, and metaphors in African American Vernacular English (Eisenhart & Edwards, 2004). As an illustration, Duran et al. (1998) conducted a qualitative study on Latine students using extant linguistic skills for learning concepts in a high school biology class. Through semiotic tools, students leveraged their linguistic and discursive practices

to construct meaning and participate in discipline-specific discourse, demonstrating the potential for drawing upon linguistic resources to enhance science learning (for a review see Lee, 2005).

Translanguaging represents an approach to language teaching that leverages students' discursive practices by mobilizing their entire meaning-making repertoires for learning (Wei, 2018). Translanguaging describes a theory from applied linguistics proposing that students tend to access their entire sense-making practices in service of learning (Garcia et al., 2017; Vogel et al., 2019). Students use their linguistic resources and move beyond named languages to access their semiotic, cultural, embodied, and social resources during the meaning-making process. According to this approach, student interaction is often fused with multiple modes of discourse where language is coupled with meaning-making modalities such as gestures, drawings, sounds, and symbols. Research has shown that by leveraging multilingual students' existing repertoires for learning, translangauging strengthens both their computational thinking (CT) and literacy skills (Vogel et al., 2020). The translanguaging approach recognizes students' home languages as assets that can be combined with their rich and varied resources to provide culturally sustaining environments for learning.

Jacob and Warschauer (2018) similarly present an asset-based approach to integrated CT and literacy instruction that seeks to leverage students existing literacy skills to develop their CT skills. The study draws from Jacob & Warschauer's (2018) three-dimensional theoretical framework examining the relationship between CT and literacy. This framework takes an asset-based approach to understanding how diverse learners leverage their linguistic resources to develop their CT skills and vice versa. Findings from classroom observations indicated that classroom teachers leveraged Latine and multilingual students' knowledge of narrative genres to teach key computational thinking concepts and practices such as sequence, abstraction and modularization, and experimentation and iteration (Jacob, Parker, & Warschauer, 2022). In leveraging these students' existing literacy resources, teachers made multiple points of connection between students' funds of knowledge and lesson content.

There is a plethora of research on how linguistically responsive instruction enhances computer science and language learning for culturally and linguistically diverse students (Calabrese Barton & Tan, 2009; Grapin et al., 2022; Moje et al., 2004). This research informs our understanding of culturally and linguistically responsive computer science pedagogy for multilingual students. For example, Nguyen et al. (2020a) use discourse-rich digital tools such as Flip Grid to better understand student learning of computer science language and concepts. Students in predominately Latine and multilingual classrooms were asked to reflect on their Scratch projects in pairs, focusing on strengths, weaknesses, and CS concepts taught and used. Findings indicated that students who used higher frequencies of CS vocabulary and exhibited greater elaboration in describing their Scratch projects tended to score higher on their programming projects. This research highlights the critical link between programming in Scratch and talking about Scratch, and how reflection activities can be used to bolster peer-to-peer interaction.

Building on this work, Nguyen et al. (2020b) studied teacher noticing of multilingual students' CS discourse. They found that while teachers initially placed greater emphasis on vocabulary usage than conceptual understanding, over time, teachers shifted their attention away from vocabulary usage to notice how students used their everyday sense-making abilities to understand abstract CS concepts. Throughout the year, teachers were provided professional development to leverage students' multiple meaning-making resources during CS instruction, representing a key pillar of culturally sustaining CS pedagogy (Kapor Center, 2021). Given the lack of formal professional development in CS education available to K-12 teachers, sharing pedagogical approaches for providing culturally and linguistically responsive CS education to multilingual and other diverse learners is critical. Beyond the strategies and theories presented for leveraging multilingual students' linguistic resources for CS learning, it is paramount that parents and teachers extend shared messaging to students that their home languages are valuable assets for learning. Unfortunately, for multilingual and Latine communities, the strong majority receive negative messaging about the use of the home language in schools (Henderson, 2017; Przymus, 2016). Prado et al. (2022) highlight how teachers and parents work in concert to center students' cultural and community knowledge across formal and informal learning environments. Using a comparison case-study design, Prado et al. (2022) found that parents and teachers engaged in shared messaging that Spanish is valuable both in and out of school. Parents and teachers framed Spanish as a resource for extending cultural pride, shaping communal legacy, and forming cultural capital. Furthermore, teachers and parents worked together to create a sense of comfort and safety in using Spanish. Creating classroom and familial experiences that value students' home languages are critical to preserving their home language use and centering community cultural wealth as a valuable asset for learning (Prado et al., 2022).

THEORETICAL FRAMEWORK

Studies in STEM identity development have traditionally focused on how students acquire competence and receive subsequent recognition upon demonstrating competence (e.g., Hazari et al., 2010). However, conceptions of competence are too often narrowly defined as prescriptive ways of knowing that are disconnected from students' lives and communities (Calabrese Barton et al., 2021). Within this lens, minoritized communities' ways of knowing, informed by their rich cultures, families, and traditions, are often delegitimized among classroom practices (Nasir & Vakil, 2017). This is especially true for multilingual students, who face compounded marginalization due to their cultural and linguistic backgrounds. These students' ways of knowing are are too often viewed as incongruent with traditional scientific ways of knowing (Reveles & Brown, 2008).

A principle governing identity development for multilingual students is that target languages can act as barriers to participation for students with diverse linguistic backgrounds (Brown & Ryoo, 2008). Brown and colleagues point to the disconnect between disciplinary practices and students' discursive identities as a site of struggle for marginalized students (Brown et al., 2005). To this end, instructional approaches that leverage multilingual students' identities strengthen students' disciplinary identification.

Our study takes an asset-based lens, grounded in a justice-centered framing of culturally sustaining education, that values the ways in which students' lived experiences and community resources contribute to meaningful types of disciplinary knowledge and practices (Calabrese Barton et al., 2021; Kapor Center, 2021). We adapt situative theories of learning (Greeno, 1997; Jacobson et al., 2016) to propose a principled system for understanding multilingual CS identity development. Situative theories of learning frame learning and its sociocultural contexts across three dimensions: *agents* (e.g., people and their interactions), *conditional actions* (e.g., social norms and values that shape interactions), and *macro-level systems features* (e.g., sociocultural and historical power dynamics; See Table 1). Framing student participation in this way acknowledges students' cultural practices and values as resources for learning that are taken up when sociocultural and historical power dynamics are just and equitable.

Although social realities are actively co-constructed, Davies and Harre (1990) grant individuals a degree of *agency* as the ability to exercise choice in how they participate in discursive practices. Cultivating student agency is essential to culturally sustaining CS pedagogy (Kapor Center, 2021). It enables students to participate in disciplinary practices that are valuable to them, position themselves as capable participants, engage in action-oriented learning, create new knowledge, and disrupt traditional scientific practices (Calabrese Barton & Tan, 2010; Ryoo et al., 2019).

To better understand equitable student CS participation, we adopt a sociocultural view of identity development that frames disciplinary practices as rooted in social interaction, which is embedded within broader social and institutional structures or *macro-level systems features*. *Macro-level systems features* reproduce power relations in which student identity enactment may be taken up or disregarded based on dominant narratives surrounding

Agents (e.g., people and their interactions)	**Conditional actions** (e.g., social norms and values that shape interactions)	**Macro-level systems features** (e.g., sociocultural and historical power dynamics)	**Asset vs. deficit-based approaches to CS identity development** (e.g., instructional approaches that value or devalue agents and their conditional actions within the context of macro-level features)	
• Students • Teachers • Administrators • Families • Peers • Community members • Policymakers	• Spoken language(s) • Everyday language • Experiential ways of knowing • Family values • Cultural values • Social practices • Community knowledge • Community resources	• National and state-wide CS policies • District and school-wide policies • Language policies • Cultural power dynamics • Racial power dynamics • Resource allocation • Immigration policies • Political reform • Media representation	<u>Asset-based power dynamics:</u> • Mobilize students' multiple meaning-making repertoires • Connect classroom learning to informal learning spaces • Provide broader context for disciplinary practices • Offer multiple opportunities for self-expression • Leverage students' strong intersectional identities	<u>Deficit-based power dynamics:</u> • Devalue students' multiple meaning-making repertoires in favor of target language norms • Separate classroom learning from informal learning spaces • Teach disciplinary practices in isolation • Limit opportunities for self-expression and creativity • Marginalize students' intersecting identities

Table 1 Theoretical model for understanding multilingual students' CS identity development.

what it means to be a competent actor. Within these *macro-level systems features*, several *conditional actions*, or mediating factors, link students' identity enactment to resultant uptake and ideologies. *Conditional actions* include students' negotiation of discursive practices, their multiple ways of knowing, and their material and social ways of being (Anderson, 2009). The coherence of these mediating factors over time helps to establish our understanding of an individual as a *kind* of person, that is, of developing a reified sense of how a person participates in and across interactions (i.e., as a good student, as a failure).

IDENTITY AND LANGUAGE

Identity is inseparable from language (Crump, 2014). We draw from Crump's (2014) theoretical framework to advance our understanding of language studies that recognize the intersections between language, race, and identity. According to Crump (2014), identity performance is connected to larger social discourses and practices, and language and identity are linked as identity is essentially constructed through language (Crump, 2014). However, identity construction is constrained by dominant narratives about what it means to be a competent community member (Crump, 2014). Unlike monolingual designations, such as English Language Learner, which describe what students with these labels cannot do, plurilingual designations acknowledge what linguistically diverse learners can do and view these resources as assets to be leveraged for learning (García & Otheguy 2020).

Culturally sustaining approaches to education view multilingual students' linguistic identities as assets facilitating learning and contributing to meaningful participation and authentic disciplinary engagement (Lee, 2021). These identities go beyond named language to encompass students' entire meaning-making repertoires (Vogel et al., 2020) as well as their everyday sense-making abilities. Students acquire cultural wealth from their homes and communities that they can draw upon to make sense of scientific phenomena. Culturally and linguistically responsive instruction mobilizes students sense-making abilities by making multiple points of connection between the curriculum and students' cultural backgrounds and interests. We build on Crump's (2014) theory to argue that identity is not only constructed through named languages but also through students' rich and varied meaning-making resources, which are rooted in their community cultural wealth.

Asset-based practices for developing multilingual students' CS identities

Drawing from multiple studies exploring multilingual student CS identity development, we provide recommendations for researchers, educators, and policymakers on nurturing multilingual students' budding CS identities. These recommendations include: 1) leveraging multilingual students' multiple meaning-making resources, 2) connecting classroom learning to informal learning spaces, 3) providing broader contexts for disciplinary practices, 4) offering multiple opportunities for self-expression, and 5) drawing on multilingual students' strong intersectional identities (Jacob et al., 2020; Jacob, Montoya et al., 2022; Jacob, Montoya & Warschauer, 2022; Scott et al., 2023; Vogel et al., 2020). What follows is a description of each.

LEVERAGING MULTILINGUAL STUDENTS' MULTIPLE MEANING-MAKING RESOURCES

Too often, educators assume that multilingual students lack the linguistic resources necessary for learning STEM content. This deficit-based approach excludes these students from equitable STEM participation. In contrast to English-only instructional approaches, plurilinguistic approaches to language instruction view multilingualism as an asset that contributes to content learning. Research corroborates this view as the multiple languages students speak have been shown to improve language and content learning compared to monolingual students (Aguayo, 2020; García & Wei, 2014). Furthermore, teachers valuing students' first languages positively shape students' perceptions of themselves as competent learners (García & Wei, 2014).

In addition to valuing named languages, many asset-based approaches to computer science instruction seek to leverage the rich and varied resources students bring to the classroom. These resources include but are not limited to their linguistic, cultural, semiotic, and embodied resources. Students draw upon their multiple sense-making abilities to access content, and in turn, these sense-making abilities can contribute to shaping disciplinary practices.

As a mechanism for drawing on multilingual students' rich meaning-making repertoires, translangauging represents a culturally sustaining pedagogy because it leverages the existing ways students make sense of content. Vogel et al. (2019) implemented a curriculum integrating computational thinking into middle school students' Spanish-English bilingual arts classes. An examination of curricular implementation found that through translanguaging, students 1) disrupted traditional boundaries between linguistic, disciplinary, and multimodal discourses; 2) infused computational literacies with their existing literacies; 3) based their understanding of translanguaging on their existing beliefs about language, and 4) engaged in translanguaging to learn about key computational thinking practices (Vogel et al., 2019). This research pinpoints how students' computational thinking

practices are intertwined with their beliefs about language and bilingualism. To this end, fostering a translanguaging stance provides safe spaces for students to draw from their cultural backgrounds during formal CS learning. This strengthens their CS identities and positions them as more capable participants in CS communities.

Translanguaging represents one of many asset-based approaches to teaching multilingual students. For pedagogy to be culturally sustaining for multilingual students, identity development should be rooted in what students already know. Furthermore, equitable CS curricula should leverage students' everyday sense-making abilities when teaching abstract concepts (i.e., algorithm, abstraction). In an asset-based course, teachers focus on understanding before terminology. This approach is particularly beneficial for multilingual students as unnecessary linguistic tasks may divert their attention from learning and understanding key concepts. The content-first approach mimics the scientific method in which scientists seek to understand a phenomenon before assigning the scientific term. This content-first approach represents an effective mechanism for teaching both language and STEM content to marginalized students (Brown & Ryoo, 2008).

Building on (Brown & Ryoo, 2008; Lee, 2021; Vogel et al., 2020), Jacob, Montoya et al. (2022) take a content-first approach to upper elementary curriculum design and instruction. Accordingly, children are taught computer science concepts in a manner that allows them to leverage their entire repertoires (i.e., cultural, linguistic, multimodal, embodied, semiotic) before receiving explicit language instruction. This type of learning often occurs through unplugged activities, or activities that teach computing concepts without computers. To illustrate, students learn the concept of loops, or the repetition of programming commands, through dance. First, students dance to a series of moves. Then the teacher asks students to identify each action in the dance. Next, the teacher and students discuss how individual moves repeat, how sequences of movements repeat, and how many times the entire dance repeats. In this way, they embody the concept before they are provided explicit instruction on the disciplinary language that uses the term loops to describe their program. The asset-based, content-first approach to computer science instruction led to the development of strong disciplinary identities for Latine and multilingual students (Jacob, Montoya et al., 2022).

The approaches mentioned above leverage the discursive practices that students develop in their homes and communities to facilitate computational sense-making and logic building. Linguistically responsive approaches to CS education go beyond written and spoken text to encompass the multiple semiotic resources students draw upon as they engage in computer science learning. These linguistic repositories, or funds of knowledge, are rooted in students' social and cultural backgrounds, which shape the myriad ways in which they make sense of phenomena. Building on multilingual students' linguistic resources incorporates their family, community, and cultural knowledge into CS classrooms, nurturing their budding interests and encouraging CS learning in both formal and informal learning environments (Kapor Center, 2021; Lee, 2021).

CONNECTING CLASSROOM LEARNING TO INFORMAL LEARNING SPACES

Students' experiences in informal learning environments intersects with students' cultural connections with their peers, families, and communities. Pinkard (2019) refers to this term as community knowledge, or the practices students engage in through their out-of-school community learning. Findings from Jacob, Montoya, and Warschauer (2022) indicated that multilingual, upper elementary students' cultural and familial identities facilitated informal learning, which afforded them additional learning opportunities and positioned them as CS experts in their communities. In turn, students were able to leverage the skills learned at home and out of school to build on their CS learning while fortifying their multiple linguistic, cultural, and disciplinary identities.

Jacob, Montoya, and Warschauer (2022) conducted a mixed-methods study on the identity formation of upper elementary, multilingual Latinas from predominantly low-socioeconomic backgrounds. In this study, socioeconomic status was defined as students who received free and reduced-priced lunch. Findings indicated that drawing upon home and community-based resources rooted in diverse group membership mobilized students' disciplinary identities for CS learning. Jacob, Montoya, and Warschauer (2022) found that family support was critical for building young Latina's intersectional identities. This is corroborated by research on Latine communities finding that *familismo,* or positive relationships built with immediate and extended family, nurtures Latine students' budding STEM identities (Rodriguez et al., 2019). In addition, students reinforced their formal CS learning through interactions with peers, family, and extended family in informal settings. Students ventured beyond classroom lessons and coding activities to practice CS in their daily lives. Through these interactions and experiences, students were able to challenge the confines of traditional disciplinary narratives, "rewriting the formula of what a computer scientist is and can be, and leaving space to include and invite other strong identities as well." (Jacob, Montoya & Warschauer, 2022).

PROVIDING BROADER CONTEXTS FOR DISCIPLINARY PRACTICES

A major goal of CS education is to develop students' understanding of the field as a lever for creating new technologies (Smith, 2016). Unfortunately, pervasive stereotyping in the field depicts CS as an innate talent (Margolis, 2017), preventing students from making authentic connections to the professions. For example, Scott et al. (2023) examine how gender stereotypes unequally shape multilingual students' participation in CS. Findings indicated that while upper elementary boys viewed CS as a vehicle for creating new technologies, many girls viewed CS as a mechanism for fixing errors and bugs. Furthermore, the boys connected CS to their own interests (i.e., gaming), while the girls viewed the computer scientist's primary responsibility as troubleshooting and fixing things. Research indicates that students show greater interest in a given skill when they are provided a broader context for learning it (Kelly et al., 2013). There have been several efforts to engage marginalized students in interest-driven computing contexts, such as leveraging the weaving traditions of indigenous families to engage students in computational thinking through the development of e-textiles (Kafai et al., 2014). Efforts such as these contextualize learning in culturally appropriate ways while building on students' cultural and community knowledge.

Computer science identity development is also strongly associated with students' perceptions of competent actors in the field. When students see computer scientists who look like them, they are more likely to identify with the discipline. Jacob et al. (2018) have iteratively refined an upper elementary Elementary Computing for All (ECforALL) curriculum to meet the needs of diverse learners. The first iteration of the curriculum integrated children's stories depicting diverse pioneers and professionals in the field of computer science to teach computer science in culturally sustaining ways. Based on teacher feedback, the second iteration integrated memorable mentors or videos describing the career paths of Latine computer scientists (Saito-Stehberger et al., 2021). These videos were accompanied by reflection prompts designed to explore the systemic and structural barriers these professionals faced in securing roles and succeeding in the CS profession. Research indicates that including same-race role models in STEM curricula positively influences Black and Latine students' dispositions and attitudes towards CS (Tukachinsky et al., 2017).

OFFERING MULTIPLE OPPORTUNITIES FOR SELF-EXPRESSION

The affordances that media-rich programming environments such as Scratch offer, such as the ability to program stories, are particularly suited to Latine communities. The tradition of oral storytelling is a widespread practice in Latine communities and serves as a sociocultural approach for passing on cultural knowledge (Leyva & Skorb, 2017; Melzi et al., 2022). Stories highlight how Latine children interpret the world through community cultural wealth (Bell & Roberts, 2010). Anchored in indigenous traditions, oral storytelling has several affordances, including transmitting important values and historical insights (Reese, 2012). Furthermore, incorporating storytelling into programming activities allows students to simultaneously engage in CS and language and literacy learning.

Jacob et al. (in press) found that predominately Latine and multilingual students in K-2 grades leveraged their knowledge of storytelling to develop their coding skills. For example, students used their understanding of well-known tales to practice abstraction by preserving critical elements of existing stories while changing other details. Other students used well-known characters, such as superheroes, to anchor their projects and reimagine possibilities for remixing existing narratives. Throughout this process, students engage in restorying, or developing counter-narratives to traditional stories (Shaw, 2020; Thomas & Stornaiuolo, 2016). As students began to reimagine and reshape disciplinary practices, they moved from identifying with computing to identifying as individuals with the agency to shape the discipline and enact change (Shaw et al., 2021).

Media-rich programming environments such as Scratch also provide a multimodal platform that enables students to express themselves in a variety of ways. Jacob, Montoya, et al. (2022) describe an upper elementary student interested in CS. She says:

> I try to make stories, conversations, and try to make games that include what I like. I already made a game, it is like a unicorn going to different backgrounds, and it makes music…and I included that because I like unicorns. It's like a way to express like what I [want], like when not like telling it in words but showing it.

In this example, the student expresses her affinity for unicorns and music. This excerpt reveals the asset-based affordances of Scratch. Students can leverage the multimodal features of Scratch by *showing* their interests and proclivities rather than *telling* them *in words*. These multimodal features enable students to engage in self-expression beyond written and spoken text. Research indicates that self-expression through multiple modalities increased student identification with and participation in CS disciplinary practices (Grapin et al., 2022).

DRAWING ON MULTILINGUAL STUDENTS' STRONG INTERSECTIONAL IDENTITIES

Grounded in the seminal theory of intersectionality (Crenshaw, 1990; Collins, 2008), Rodriguez and Lehman (2017) argue that educators need to account for issues of intersectionality that shape CS identity formation to create more equitable learning environments. We define intersectionality as the multiple identities individuals construct that shape their experiences within specific contexts, such as multilingual students who are Latine in computing, and how systemic issues produce compounding inequities for marginalized groups (Crenshaw, 1990; Rodriguez & Lehman, 2017). Acknowledging intersectionality in identity construction frames marginalized students' experiences as being shaped by issues such as class, gender, and race (Collins, 2008; Crenshaw, 1990; hooks, 1992). The broader public perception of these identities may contribute to the marginalization of students who belong to underserved groups.

Much of the identity-based scholarship has focused on specific groups (i.e., women, students of color, multilingual students, and students from lower socioeconomic backgrounds) (e.g. Cohoon & Aspray, 2008; Margolis, 2017), but little research explores how these identities intersect to promote identification or disidentification with computing. The latter approach can advance our understanding of the dynamism, multiplicity, and conflictual nature of identity development and the diverse resources that students from intersectional groups bring to bear.

For multilingual students, as with other groups rooted in other communities, linguistic, social, and cultural issues intersect to shape diverse students' identities. Aguayo (2020) describes the interconnectedness of ethnic identity and cultural identity. In her dissertation, Aguayo (2020) examines the relationship between identity, language, and race from 13 Latine individuals with English learner-labeled backgrounds. She found that many reported being stigmatized and delegitimized because of this label. When coupled with Latine identity, the participants felt that the stigmatization was compounded and resulted in cultural desensitization, as an attempt to bridge their Latine identities with their linguistic identities was futile (Aguayo, 2020).

Exploring issues of intersectionality for multilingual students have multiple affordances. On the one hand, examinations of intersectional identity construction advance our understanding of how racism and structural barriers are compounded for particular groups (Rodriguez & Lehman, 2017). On the other hand, research also underscores how students' intersecting identities bring valuable contributions to the classroom that lead to greater identification with computing (Author et al., n.d.). When teachers leverage students' rich and varied resources, the latter begin to develop agency and become active participants in shaping the field.

DISCUSSION AND IMPLICATIONS

Findings from this paper highlight the value of connecting students' formal CS learning experiences with their rich cultural backgrounds and funds of knowledge. Based on these findings, we discuss the implications of culturally sustaining CS practices for researchers, educators, and policymakers. In this paper, we provide five culturally sustaining practices that teachers can implement in their classrooms to develop multilingual students' CS identities, including 1) leveraging multilingual students' multiple meaning-making resources, 2) connecting classroom learning to informal learning spaces, 3) providing broader contexts for disciplinary practices, 4) offering multiple opportunities for self-expression, and 5) drawing on multilingual students' strong intersectional identities (Jacob et al., 2020; Jacob, Montoya et al., 2022; Jacob, Montoya & Warschauer, 2022; Scott et al., 2023).

Understanding the sociocultural and linguistic factors that shape CS instructional practices enables researchers to advance their understanding of culturally sustaining CS pedagogy, providing equitable and accessible learning opportunities for marginalized students. While computer science identity development has typically been framed around notions of competence, this paper highlights the sociocultural and linguistic dimensions contributing to multilingual students' CS identity development. Culturally sustaining CS pedagogy can is fostered when teachers leverage the *conditional actions* that mediate student identity enactment. For example, teachers can make connectione between CS curricula and students' lived, familial, and community-based experiences. Drawing on students' funds of knowledge in this manner in turn strengthens their CS identities (Jacob, Montoya et al., 2022; Vogel et al., 2020). As multilingual students draw upon their community cultural wealth as assets for learning, they begin to disrupt disciplinary practices and act as change agents in their communities (Calabrese Barton et al., 2021; Kapor Center, 2021). To this end, culturally sustaining pedagogy can be operationalized through the five practices recommended in this paper to nurture multilingual students' budding CS identities.

In addition to this contribution, this paper puts forth a theoretical framework for understanding the *actors* (e.g., people and their interactions), *conditional actions* (e.g., social norms and values that shape interactions), and *macro-level system features* (e.g., sociocultural

and historical power dynamics) that shape multilingual students' CS identity development. What follows is a principled example that illustrates how the theoretical model relates to the culturally sustaining practices put forth in this paper. In particular, we focus on the fourth asset-based practive listed above; offering multiple opportunities for self-expression. As multilingual students express their identities in Scratch, they assert their *agency*, which is rooted in individual characteristics (i.e., languages spoken, knowledge structures, motivation). At the same time, student expression is mediated by *conditional actions*, or sociocultural norms and values influencing individual behaviors. For example, students may draw from their everyday language, multiple ways of knowing, cultural identities, familial identities, and/or community knowledge to make sense of phenomena. The degree to which students' identity expressions and their underlying sociocultural norms and values are taken up in a given community depends heavily on *macro-level system features* (social and historical power dynamics governing institutions). For example, if students express their identities by representing their cultural values and traditions in Scratch, but at the systemic level students' cultural practices are devalued, then their identity enactment will be disregarded. The conditions surrounding these deficit-based *macro-level systems features* lead to student disidentification with CS. However, if students' cultures are embraced and celebrated at the *macro-level*, their identity enactments will be taken up within their communities, thereby strengthening multilingual students' identification with CS.

The situative theoretical framework presented in this study can be practically used as a culturally sustaining model to aid CS teachers during professional development and in the preparation of lesson plans. For example, teachers can identify and mobilize the *conditional actions*, or sociocultural resources (e.g., spoken language, everyday language, cultural values) that students leverage as they make sense of classroom content. It can be further used to guide educators and policymakers in understanding the types of supports necessary to ensure that CS classrooms are culturally sustaining at the institutional level. In particular, policymakers should pay attention to the *macro-level systems features,* or the systemic policies and power dynamics that shape CS learning for multilingual students.

To make culturally sustaining CS classrooms feasible and sustainable, educators should focus on the policy level to increase culturally sustaining CS learning opportunities for students on the margins. Across the US, efforts are being made at the local and statewide level to offer more computer science courses in high school and to have these courses count towards graduation requirements. But the question remains as to who these courses are serving. While AP computer science courses are increasingly enrolling low-income students and students of color, issues of representation and gaps in performance remain critically problematic (College Board, 2020). Several states are working to develop computer science credentialing programs, yet it remains unclear the extent to which this preparation will include courses on culturally and linguistically sustaining pedagogies. This paper's findings can inform educational policymakers on leveraging culturally sustaining pedagogies in CS teacher preparation and professional development programs to increase access to and identification with CS curricula for culturally and linguistically diverse students.

There are several limitations to this study. First, the five practices outlined in this review are not exhaustive but are representative of major findings from studies to date that examine multilingual students' CS identity development. Nor are the components in the theoretical framework exhaustive of possible *agents*, *conditional actions*, or *macro-level systems features* that frame the topic. The model presents preliminary principles for understanding the principles, components, and dynamics that shape multilingual students' CS identity development. In the future, educational researchers can adapt or build upon this model to provide a more comprehensive understanding of multilingual students' CS identity development. Finally, the research on multilingual CS identity development is nascent. While much of the research to date has focused on mixed methods and case study designs, future research can test the efficacy of these culturally sustaining practices using experimental and quasi-experimental methods. Examinations such as these will provide a firm empirical foundation for understanding the relationship between culturally sustaining pedagogy and CS identity development for diverse learners.

CONCLUSION

We must provide early exposure to culturally sustaining CS opportunities for diverse learners. This exposure is linked with later interest in CS careers (Wang et al., 2016) and greater CS identity development (Jacob, Montoya, et al., 2022; Jacob, Montoya & Warschauer, 2022). In this paper, we provide several practices outlining how researchers, teachers, and educational policymakers can provide culturally sustaining CS educational opportunities for Latine and multilingual students. While there is much need for top-down reform in CS education, these recommendations can also be adopted at the local level to address social, cultural, and economic constraints and contexts.

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COMPETING INTERESTS

The authors have no competing interests to declare.

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