Conceptualizing Culturally Meaningful Participation in Undergraduate Mathematics

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Participation in undergraduate mathematics courses is viewed as an important metric for assessing student learning and motivation, especially in active learning classrooms. However, engagement has been understood through a narrow lens, which overlooks the way students—especially students of color—engage with mathematics courses and positions them as disengaged. In this theoretical report, we introduce the idea of culturally meaningful participation in undergraduate mathematics to capture the organic ways that students of color draw upon cultural resources to create spaces for engagement in or with their mathematics courses. We draw upon Yosso's Community Cultural Wealth Framework and the notion of Ong's STEM counterspace to support our theorizing. We argue that CME recognizes the assets that students bring to support their engagement with mathematics and also illuminates how these assets are drawn upon. We argue that CME has the potential to support broader anti-deficit efforts in undergraduate mathematics education.

Keywords: participation, culture, community cultural wealth, language, counterspaces

> En unas pocas centurias*, the future will belong to* the mestiza*. Because the future depends on the breaking down of paradigms, it depends on the straddling of two or more cultures. By creating a new* mythos-- *that is, a change in the way we perceive reality, the way we see ourselves, and the ways we behave*-- la mestiza *creates a new consciousness* (Anzaldúa, 1987).

The undergraduate mathematics education landscape has changed significantly over the last 30 years. Driven by social progress and university commitments to DEI, mathematics classrooms now serve a more racially and culturally diverse student body. However, racially minoritized students remain underrepresented in STEM education (National Science Foundation, 2016), persist in STEM at lower rates (Whitcomb & Singh, 2021), and often experience inequitable learning experiences (Eddy et al., 2015). These patterns underscore the ongoing need for equity and inclusion efforts in both research and practice.

While there have been important efforts to improve access in undergraduate mathematics (e.g., including equity in IBL, Laursen & Rasmusen, 2019), as a field, we still struggle to understand how to center identity and culture in these efforts. Often, culture is an integral part of students' identities, shaping how they interpret the world and interact within it. As the quote above reminds us, students' abilities to straddle multiple cultural worlds and transform dominant narratives can foster new ways of imagining participation in mathematics education.

In this paper, we introduce a theoretical perspective for understanding student participation through a culturally responsive lens. This perspective, which we call c*ulturally meaningful participation,* counters deficit narratives about students of color by highlighting the cultural resources that they draw upon to foster meaningful mathematical engagement in undergraduate mathematics courses. It acknowledges that mathematics classrooms are racialized and gendered spaces, which inevitably shape how students navigate their engagement. As such, we argue that culturally meaningful participation needs to account for ways students engage with mathematics and their course outside of the formal classroom space. To build this idea, we first discuss how student participation has been conceptualized in undergraduate mathematics.

Undergraduate Mathematical Participation

Classroom Participation

The shift from lecturing to active learning has significantly reshaped the undergraduate mathematics classroom experience and how instructors and researchers perceive student engagement through different ways of participating. In lecture-based classrooms, participation generally involves sitting, listening, taking notes, and occasionally asking or answering questions. In contrast, in more active classrooms, students are expected to work collaboratively, discuss ideas with peers, and explain their thinking to the class. Active learning classrooms give more opportunities for students to speak and share their ideas, and largely this type of visible forms of classroom participation have become the main indicators (and measurements) of student engagement, learning, and motivation.

The shift in perspective on participation is consistent with the social turn in mathematics education research, which reflects an inherent change in the conceptualization of learning towards "the person-acting-in-*social- practice,* not person or their knowing on their own" (Lerman, 2000, p. 25; see also learning as participation metaphor in Sfard, 1998). Studies have examined participation as an important metric related to equity (e.g., Ernest et al., 2019; Reinholz et al., 2022). This type of work importantly highlights systemic inequities in the classroom. However, when we view their findings alongside common reactions from teachers related to increasing participation, they begin to tell a story. For example, teachers in Rios & Lozano (2025) shared comments such as, "It is hard to get them out of their comfort zone /…/ it's like an elastic band, you can try to pull them out but sometimes they want to snap back," or "At risk" students have a "tendency to hide in the background." Together they become a part of a broader discourse concerning the underparticipation of students of color in mathematics classrooms.

This deficit discourse often manifests in the classroom as deficit positioning of students who "do not" participate. For example, Rios (2024) specifically documents how a multilingual student from Guatemala felt that her teacher positioned her as not engaged or interested because she was often quiet during class time, when in fact it was a coping mechanism for the linguistic microaggressions she experienced by her group members. Other studies have also documented that active participation in the classroom is often more challenging for students of color, given the racialized and gendered nature of our society and its role in classroom dynamics. For example, Battey et al. (2022) reported that "withdrawing participation" was a common response among their participants in managing "cognitive labor from discouraging events" (p. 104).

We argue that the reliance on visible and normative forms of participation creates space for deficit interpretations of students of color's participation in undergraduate mathematics. Along with the social turn in mathematics education, deficit narratives might evolve from fixating on deficiencies in students' mathematical sensemaking (Adiredja, 2019) to perceptions of underrepresented students' "struggle" with classroom participation. As the field continues to work on understanding ways to make the undergraduate classroom more inclusive (e.g., Downing & McCoy, 2021; Jett, 2013), we now consider other spaces that might be more culturally affirming.

Participation Outside of the Classroom

Much of the learning in an undergraduate mathematics course occurs outside of the classroom, especially with lecture-based courses. Traditionally, built-in support at universities for learning outside of the classroom consists of attending office hours and going to mathematics

tutoring centers. So, another way to assess students' participation is through their use of these support services. Research has documented the (racialized) nature of attending office hours for many students of color as related to confirming negative stereotypes (Dauber & Hsu, 2025; McClain, 2014). Thus, relying on such a normative form of participation, again, leads to deficit positioning of students of color.

For this reason, research has begun exploring the importance of STEM *counterspaces* in higher education (Ong et al., 2018). Counterspaces are spaces that lie outside of traditional course structures but provide students of color with environments where their academic and personal identities align and are affirmed with others who share their identity. Examples of such counterspaces include cultural resource centers for different social identities (e.g., African American Student Center) and national organizations like SACNAS (Society for the Advancement of Chicanos/Hispanics and Native Americans in Science).

While these spaces have been shown to support identity development (e.g., Leyva, 2021; McGee & Martin, 2011), they tend to exist outside of the academic departments. A notable exception is the work of Uri Treisman (Treisman, 1992). Treisman observed the cultural practice of Chinese students forming study groups with other Chinese students, where they worked on mathematics collaboratively and built community with upper classmen. This can be seen as an example of a culturally affirming space created by students where they engaged in mathematical learning.

Building on this idea, we are curious of other ways that students of color engage in practices that support their learning that are culturally meaningful for them. In particular, if we can identify cultural resources that students use to support participation in mathematics, then we can begin to challenge deficit discourse as related to underparticipation of students of color in mathematics. To help us conceptualize what other cultural resources students might use, we draw upon Yosso's (2005) Community Cultural Wealth (CCW) framework from higher education.

Community Cultural Wealth (CCW)

The Community Cultural Wealth (CCW) framework (Yosso, 2005) challenges deficit perspectives about the achievement and college readiness of students of color (Valencia, 2010). CCW focuses on the resources and capitals nurtured by their communities. Yosso argues that cultural wealth are vital resources that help students of color successfully navigate higher education. CCW identifies seven capitals: 1) aspirational capital, the ability to maintain hopes and dreams in the face of oppression; 2) linguistic capital, the intellectual and social skills from understanding of multiple languages; 3) familial capital, "cultural knowledge nurtured among familia (kin) that carry a sense of community history, memory and cultural intuition" (p. 79); 4) social capital, resources for and from the community; 5) navigational capital, skills to navigate spaces that were not created for them; 6) resistant capital, knowledge and skills learned from opposing inequalities and injustices; and 7) spiritual capital, "a set of resources and skills rooted in a spiritual connection to a reality greater than oneself" (Huber, 2009, p. 721).

A few studies have applied this framework in the context of undergraduate STEM education (Dika et. al, 2018; Peralta et al., 2013; Luna & Martinez, 2013; Samuelson & Litzler, 2016). These studies have primarily focused on identifying different forms of capital—primarily familial and aspirational—rooted in students' communities as motivation for students in pursuing and persisting in their education (e.g., Dika et al., 2018; Samuelson & Litzler, 2016). In contrast, Rios-Aguilar et al. (2011) discuss the notion of *using* cultural capital, that is, the "the mobilization of cultural resources" (p. 170), in understanding the experiences of students of color in STEM. The authors highlighted the important distinction between the possession of cultural

capital vs. the activation of cultural capital and what contexts allow students to activate these resources. To contribute to this work, we are interested in how students draw upon these forms of capital in their mathematical practice (not just that they have them), and how these capitals impact students' engagement beyond serving solely as motivation.

Defining and Illustrating Culturally Meaningful Participation

We assert that students of color possess important culturally nourished resources that they can draw upon to support their mathematical practice at the undergraduate level. The CCW framework identifies such resources which center language, identity, community, connection, and resistance. We call this *culturally meaningful participation in mathematics*—the practice by which students participate in important mathematical activities as part of their mathematics courses as a result of drawing upon their community cultural wealth. We argue this type of practice allows students of color to creatively navigate these spaces, without leaving their identities, communities, and values behind for the sake of STEM assimilation.

To illustrate what culturally meaningful participation in undergraduate mathematics (and STEM) courses might look like by drawing from two datasets: 1) interviews with five undergraduate students who self-identified as Hispanic/Mexican and participated in a summer calculus bridge program (previously analyzed and discussed in Adiredja & Rios, 2019), and 2) interviews with 28 multilingual, undergraduate students about their experiences in precalculus and calculus courses that use active learning (discussed in Rios, 2024). Both datasets are rich in examples of how students found avenues to engage in and access supports in their courses, by leveraging what we recognize as community cultural wealth. We start with two short examples of social capital before delving deeper into examples of participation that stem from students' linguistic and resistance capital.

Illustrating social capital, Marco was a student studying STEM who identified as Hispanic and grew up in a small, "tight-knit" border town. When Marco started taking STEM courses at the university, he already had an established support system of friends and cousins from his home town who were also pursuing STEM. He described going to their dorm late at night to get help on an assignment, and he jokingly added that they were also "cooking up some chicken" for him. This form of social capital, rooted in his hometown community, became his main way of participating in his courses. In another example, Ahmad, a student who arrived in the U.S. as a refugee from Iraq, sought support from his father when he was struggling in his calculus course. His father then connected him with his own former high school mathematics teacher, who was still in Iraq, and provided Ahmad with tutoring over video chat. This became an important (social) resource for Ahmad and a way that he was engaged in the course, which was facilitated through his father (familial capital). This was a different way of participating than attending office hours that could have been easily overlooked by his instructor. Ahmad was drawing on a valuable (family-based) resource to support his learning and engagement in calculus.

"My time to shine"

To illustrate culturally meaningful participation using resistance capital, we share Lesli's experiences in calculus. Lesli identified as half Mexican and half Puerto Rican, and was a determined and accomplished undergraduate student studying chemistry. In her Calculus II course, Lesli navigated what were likely racialized and gendered interactions and to integrate into a community by joining in a high-status study group. This study group worked together on calculus in the library and were not initially accepting of Lesli:

> I walked in and they were working on some questions, and everyone was kind of skeptical, like, 'Oh, this is a new girl' /.../ I was having issues with a similar type of problem that they were having. So I asked them questions on how they did them and what not. And I could sense already that they were like, "Oh no, she doesn't know enough."

Lesli sensed their gendered skepticism, but resisted:

> So then we worked on another question, and that question for them was super hard. No one could get it, out of all the people who were there, probably six guys /…/ Thankfully that was a question that I knew like off the top of my head because I had spent a good hour working it out by myself earlier that day /.../ I was like, "This is my time to shine!" /.../ After that it was like, I had been accepted.

Lesli summarized the experience of being accepted by stating: "I feel like you kind of have to prove yourself to get in. That's why my mom calls it 'the mafia' because not everyone gets in".

Despite having to prove herself, which we interpret as drawing upon her resistance capital, Lesli attributed much of her success in calculus II to her participation in this study group. She described the members of her study group as her closest friends: "I've been able to find a group where we truly care about each other and about each other's learning because we've developed that kind of friendship."

We learned that Lesli's ability to resist was rooted in her community and cultural upbringing. As a student from the "South side," Lesli shared:

> Just coming from a high school like Central, I know when I was in high school people would talk about, 'Oh she's a central [an under-resourced school] girl who won 2nd place at the national medical spelling bee /…/ She came out of central, from the South side, where she shouldn't have, and all those accomplishments'. So I came from a place like that, and so I feel like my background helped me to be able to handle criticism and skepticism and indifference.

Here, Lesli acknowledged the narrative and lower expectations people placed on her. At the same time she reclaimed this experience by recognizing that being from her community allowed her to develop important tools for handling microaggressions:

> Indifference can pretty much kill you, if you let it kill you. And I think from the interaction that I get with other groups that may look down on me. Beside skepticism, criticism, looking down, I think it's the indifference that hurts the most I'd say. You know we as humans, we have to get over it and we have to just ask questions and you have to force yourself to interact with them /…./ it's just a matter of re-centering yourself and re-wiring yourself to believe that what you're doing is worth the sacrifice and un-comfortableness /…/ In my experiences I have had to make myself notable, like you know, I am here too. I am a thinking human being. I have a brain you can ask me too. I'm here to help you too.

Being able to navigate and ultimately resist these deficit narratives were a part of Lesli's lived experience—something that was meaningful to her and a source of pride. Thus, for Lesli, being able to participate in a high-status study group, and the benefits she gained from it, exemplified a culturally meaningful participation.

"Speak tu propia lengua, no?"

To illustrate how linguistic capital can foster culturally meaningful participation, we share examples from two students: Veronica and Sai. Veronica grew up in Mexico and moved to the United States during high school. As a bilingual STEM student, Spanish was very important to Veronica and she used this cultural capital to find community within her STEM courses.

Veronica described how Spanish helped her form a special connection with other Spanish-speaking students:

> I just came from [Mexico], I still have my Mexican culture, no? So I think language is a big plus for me. Not just academic wise, just conversation you know. You can just talk more easy. You can joke more easy /…/ In upper division [STEM courses], you mostly see Americans and when I see somebody that speaks Spanish too, I get like 'oh wow, you speak spanish? Me too!' and then we just speak Spanish from there on now. And it's kind of really nice to speak your own language, no? Cuz you can say different things.

Veronica explained that when she had a question, the first resource she turned to was these friends because she could explain her question in Spanish. Veronica also described getting help for her STEM courses from a bilingual graduate student, because he could explain in Spanish:

> Last semester I had a lab TA that-- He was Mexican. And then, I would actually go to his office hours because he could explain to me in Spanish, and um, I just think it's a-- I don't know how to explain, you just have a connection.

She often attended his office hours instead of her professors, sharing: "I feel like I ask [professors] things and they get something else for some reason and they give me that answer and I don't really like saying, 'Oh. That's not what I meant'". Instead of utilizing more conventional course supports, Veronica drew on cultural knowledge—Spanish—and the connection through shared language identities to find support systems in her STEM courses.

Similarly, Sai, an international student from India, found a "good support system" in his calculus II class by leveraging his linguistic capital as a Hindi speaker:

> So whenever I see an Indian in my class I message him personally and try to be friends with him and whenever I talk to him I use Hindi and for solving math I use English while talking to him in Hindi. So bilingualism has introduced that concept of familiarity. /…/ I've seen this happen a lot of times, just switching that mode from English to Hindi is the form of connection. We're like, we come from the same background, we share the same you know, history, same language and that ends up, you know, bonding us together.

Additionally, Sai intentionally enrolled in a section of calculus II taught by an Indian graduate student, because he knew he could connect with him and would be able to ask questions in Hindi. Sai was one of the few students that regularly attended office hours, which he attributes to feeling "more of a connection" and "more comfortable" with a Hindi-speaking instructor.

Both Veronica and Sai's course experiences offer another illustration for culturally meaningful participation. They both used their linguistic capital to find community and spaces where they could participate in mathematics in a way that affirmed their linguistic (and cultural) identities.

Discussion and Implications

In this paper, we argue that a narrow, normative lens on assessing participation misses the humanistic dimension of how each student navigates who they are in their mathematics courses. It also neglects the important role of culture and identity in how students choose to participate. To capture this, we propose the notion of *culturally meaningful participation* to highlight that students of color bring meaningful cultural resources they draw upon to facilitate participation in undergraduate mathematics courses. As the examples we share illustrate, participation often occurred through unofficial channels and spaces outside of the classroom (e.g., study groups, lab TA's office hours, tutoring with a family friend). These examples serve as counterstories capturing the dedication students have for their education and the rich ways they participate in

their mathematics courses. By leveraging their resources to participate, students do so in a way that, from our perspective, affirms their culture, community, family, and lived experiences.

Our conceptualization of culturally meaningful participation in undergraduate mathematics contributes to broader anti-deficit effort in undergraduate mathematics (Adiredja, 2019; Peck, 2021). As we noted, relying on traditional forms of assessments of participation, whether it is through verbal participation in the classroom or attending office hours contribute to deficit discourse about students of color's participation in mathematics. Our work expands the definition of participation beyond traditional measures, which recognizes students' cultural resources they use to participate in mathematics, and also disrupts such deficit discourse. Theorizing about and illustrating culturally meaningful participation has the potential to provide a lens for researchers and practitioners to think about equitable participation in mathematics.

We hope that empirical studies can begin to further document and track the kinds of participation we introduced in this paper. In teaching, addressing issues of underrepresentation in classroom participation, we can go beyond the fixation of getting students of color to speak more. Instead, we can begin discussing the potential of grouping students based on a shared cultural identity, helping students connect with others and form study groups outside of the classroom, connect students with TAs or other instructors who share an important identity, or even noticing and celebrating acts of resistance and perseverance in the classroom. We argue that centering cultural responsiveness in discussions of participation can help researchers, instructors—and mathematics departments more broadly—recognize the resources students bring to their mathematics courses and reimagine learning experiences that mirror the stories of participation rooted in culture that students engaged in and valued.

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