CHARACTERIZING OPPORTUNITIES FOR MATHEMATICAL AND SOCIAL PARTICIPATION: A MICRO-ANALYSIS OF EQUITY IN SMALL-GROUP ZOOM INTERACTIONS

Heather Fink
University of California, Berkeley
hfink@berkeley.edu

This study focused on issues of equity related to small-group participation in a distance learning calculus class. Equity is defined as the fair distribution of opportunities for students to participate and learn. I examined how opportunities for mathematical and social participation were constructed through acts of positioning for four students. Findings suggest that creating fair opportunities requires: 1) conceptualizing opportunities for participation as connected to students' positionings and developing identities, 2) acknowledging that what counts as an opportunity for one student does not necessarily count as an opportunity for another student, and 3) leveraging both mathematical and social contributions in creating equitable, supportive, and intellectually rich learning communities.

Keywords: Classroom discourse; Equity, inclusion, and diversity; Online and distance education

Educational inequities constrain the opportunities students have to participate and learn in math classes (Cobb & Hodge, 2002; Esmonde, 2009). Often rooted in societal-level biases, inequities are promulgated by patterns of marginalization (e.g., racialization, sexism) that distribute power unfairly through classroom interactions (Esmonde & Langer-Osuna, 2013; Gutiérrez, 2012; Martin, 2009). Inequities occur when some students are positioned as having more to contribute than others (Herbel-Eisenmann, Wagner, Johnson, Suh, & Figueras, 2015) and/or face additional barriers to participation (Leyva, Quea, Weber, Battey & López, 2020). Pursuing equity requires studying classroom interactions at a micro-scale to understand how inequities play out for individual students in specific classroom contexts (McDermott & Roth, 1978). Equity is conceptualized as the fair distribution of opportunities for students to engage in meaningful ways, supporting the development of rich content knowledge and positive identities (Esmonde, 2009; Schoenfeld, 2014). This study focuses on micro-level issues of equity related to small-group participation in math. I examine how opportunities for mathematical and social participation were constructed through acts of positioning in a distance learning calculus class.

Small-group learning tasks hold potential to address issues of equity by engaging all students in meaningful content while also supporting students in building positive identities as thinkers, learners, and community members (Boaler & Staples, 2008; Cohen & Lotan, 2014). While potential benefits are substantial, implementing successful small-group learning is not easy (Barron, 2003), and working with virtual learning constraints makes it even harder (Wong, 2020). In video-conferencing platforms like Zoom, students face additional physical and social barriers to interaction (e.g., background distractions, ambiguous body language, and limited visibility of student work). For some students, Zoom breakout rooms have been the only opportunity to interact with people outside of their immediate families, exacerbating the necessity for small-group interactions to support both students' academic and social needs.

This study explored the interactions of four students working on a small-group task, focusing on the construction of opportunities for mathematical and social participation. Specific research

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questions are: *1) How did each student contribute during the task? 2) How were students invited to contribute? 3) How did group participants respond to students' contributions?*

Theoretical Framework

This study is informed by sociocultural and situated theories that consider learning as occurring through participation in cultural activities (Lave & Wenger, 1991; Vygotsky, 1978). Classroom participation is defined broadly and includes more than content-related talk. Non-verbal forms of communication are believed to be valuable for learning (Esmonde, 2009), and "off-task" or social participation is deemed relevant and potentially productive (Gholson & Martin, 2014; Langer-Osuna, Gargroetzi, Munson, & Chavez, 2020). Learning is defined as changes in students' participation in collective classroom practices (Lave & Wenger, 1991). Students' participation in learning activities is a function of the opportunities they are given to participate (Gresalfi, Martin, Hand, & Greeno, 2009); if opportunities to participate are unfairly distributed, then learning will be inequitable as well. Opportunities to participate are shaped by the roles and responsibilities students are assigned through acts of positioning (van Langenhove & Harré, 1999). Through positioning, racialized and gendered narratives (i.e., storylines) come into play (Esmonde & Langer-Osuna, 2013; Reinholz & Shah, 2018). As students interact, expectations are negotiated for what each student can and should do, distributing power among students (Herbel-Eisenmann et. al., 2015). Equitable learning processes require that each student be positioned as a valuable contributor to their own and their peers' learning. Students positioned with competence and authority have more opportunities to participate in consequential and influential ways, and therefore have better access to rich mathematical learning and identity development (Cohen & Lotan, 2014; Gresalfi et al., 2009; Langer-Osuna, 2011).

Methods

Data Collection

Participants. Classes used Zoom for fully distanced learning at the time of observation (Feb. 2021). The focal group consisted of four 12th grade students in a Calculus AB course at an urban public high school: Yonas, Guadalupe, Hosein, and Elijah (pseudonyms). Guadalupe is the only student in the group who identifies as female, and Elijah is the only student who identifies as White. Ms. B was the calculus teacher. Mr. K was a student teacher. Ms. F was the researcher (began daily observations Sept. 2020). Participants are shown in Figure 1 (with permission).

Figure 1: Participants in the Focal Group on Zoom

Task. Students joined Zoom breakout rooms to work on a Related Rates problem. They had not yet received formal instruction on this topic. The teacher wanted students to think about the underlying ideas before formalizing solving strategies. Students were instructed to work with their teams. The problem read: *1. A ladder leans against a wall. It begins to slide down the wall.*

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Does the top of the ladder move at the same rate as the bottom of the ladder? 2. Suppose the bottom slides away from the wall at a rate of 1 ft/sec. How fast is the top of the ladder sliding down the wall when the bottom of the ladder is 6 ft from the wall? Assume the ladder is 10 ft.

Video. Video of the focal group was recorded using Zoom functionality. The video was approximately 10 minutes long, the amount of time the students spent working on the task.

Data Analysis

Video was transcribed for speech and salient expressions/gestures, then divided into *contributions*. A contribution was uninterrupted speech by one person of a single *type* (defined below). Sometimes a single talk-turn contained two contributions, such as when Yonas began reading the problem aloud (contribution 1), then shared mathematical reasoning (contribution 2). All talk was coded as either a mathematical or social contribution. Codes were assigned to every contribution based on *acts of positioning* (van Langenhove & Harré, 1999), operationalized into three categories: contribution types, contribution invitations, and contribution responses.

Contribution types. Each contribution is an act of positioning (Gholson & Martin, 2014). The contributing student positions themself through the type and content of their contribution. Did the student contribute sound mathematical reasoning? Or did they contribute a comment that made everyone smile? Contribution *types* were coded as: Asks a question, Makes a comment, Shares mathematical reasoning, Shares solution with reasoning, Shares solution without reasoning, Expresses agreement, Expresses disagreement, or Reads the problem aloud.

Contribution invitations. Each contribution invitation is an act of positioning (Langer-Osuna, 2011; Radinsky, 2008), including explicit and implicit prompts. Students position themselves and each other depending on how contributions are prompted. Was a student called on by name to contribute a math idea? Or did they interrupt another student to share an idea with seemingly no invitation at all? Contribution invitations were coded as one of the following: Participant actions, Silence, or Interruptions. Invitations were coded as *Participant action* when the words or actions of someone in the group prompted a contribution from someone else, either explicitly or implicitly. The person whose actions invited the contribution was also coded. Invitations were coded as *Silence* if a contribution was made when no one was speaking and was not connected to previous contributions. *Interruptions* were coded when someone cut off another person's contribution, indicating a lack of invitation.

Contribution responses. Participants' responses to contributions are acts of positioning as well (Anderson, 2009; Hand, 2010). Students are positioned by their peers and teachers through the reactions they get to the contributions they make. Is the contribution met with explicit affirmation? Is the validity of the contribution challenged? Or is the contribution ignored? Contribution responses were coded as: Positive (verbal agreement or smile), Negative (verbal disagreement or interruption), or Neutral (silence or no change in facial expression).

Findings

Collectively, findings address the central question of how opportunities for mathematical and social participation were constructed for each student. Findings are organized by the specific research question: *1) How did each student contribute during the task? 2) How were students invited to contribute? 3) How did group participants respond to students' contributions?*

Contribution Types

Findings in this section address the question: *How did each student contribute during the task?* Contributions were quantified by totaling the number of words spoken and the number of contributions made by each student, shown in Table 1. Words and contributions were categorized as either mathematical or social. The number of words metric provides insight into the amount of airtime occupied by each student without any indication of contribution quality.

Table 1: Number of Mathematical & Social Words and Contributions by Student

	Yonas	Guadalupe	Hosein	Elijah
# of Mathematical Words Spoken	454	55	227	213
# of Social Words Spoken	9	130	1	0
TOTAL # of Words Spoken	**463**	**185**	**228**	**213**
# of Mathematical Contributions	23	4	10	10
# of Social Contributions	2	9	1	0
TOTAL # of Contributions	**25**	**13**	**11**	**10**

Yonas spoke more than twice as many words as his peers, resulting in a total of 25 contributions, 23 of which were mathematical. Hosein and Elijah both spoke over 200 words, resulting in 10 mathematical contributions each. Hosein had a one-word social contribution as well. Unlike her peers, Guadalupe's social words and corresponding social contributions more than doubled her math words and math contributions. Table 2 shows the types of contributions for each student.

Table 2: Number of Mathematical & Social Contributions by Type by Student

			Yonas	Guadalupe	Hosein	Elijah
# of Contributions by Type	Mathematical	Asks a question		1	3	
		Makes a comment	7		2	1
		Shares mathematical reasoning	7		3	1
		Shares solution with reasoning	2	1	1	2
		Shares solution without reasoning		1		
		Expresses agreement	3	1	1	4
		Expresses disagreement	1			2
		Reads the problem aloud	3			
	Social	Asks a question		2		
		Makes a comment	2	7	1	

All students shared at least one solution with mathematically valid reasoning and each expressed verbal agreement with a peer at least once. Yonas and Elijah were the only students who expressed disagreement, and Guadalupe and Hosein were the only students who asked questions. Based on this data, it appears Yonas contributed the most in terms of the quantity of math interactions, and Guadalupe contributed the most in terms of social interactions. Hosein and Elijah both made considerable math contributions, while Guadalupe shared some math ideas too.

Contribution Invitations

Findings in this section address the question: *How was each student invited to contribute?* Invitations were categorized as either mathematical or social. From there, invitations were determined to be connected to participants' actions, silence, or interruptions. The number of invitations by type and by student are presented in Table 3.

Table 3: Invitations to Contribute by Type and by Student

	Mathematical				Social			
	Participant Actions	Silence	Interruptions	Total	Participant Actions	Silence	Interruptions	Total
Yonas	12	10	1	23	2	0	0	2
Guadalupe	4	0	0	4	8	1	0	9
Hosein	4	5	1	10	1	0	0	1
Elijah	6	2	2	10	0	0	0	0

Table 3 shows that invitations for Yonas's and Hosein's mathematical contributions were relatively balanced between participant actions and silence (Yonas: 12 participant actions vs. 10 silence; Hosein: 4 participant actions vs. 5 silence). The relatively high number of silence invitations suggest that Yonas and Hosein were comfortable initiating math contributions without an explicit prompt. Yonas and Hosein also had one interruption each, but both students apologized. When Guadalupe was speaking, Yonas said, "Oh my god. Wait. Sorry, sorry. I just had a theory." When Yonas was speaking, Hosein said, "Um, Yonas? I'm sorry to interrupt. I have an idea." Elijah's math contributions were most often connected to other participants' actions (6 out of 10 invitations). Elijah also made the same number of contributions when the room was silent as when someone else was speaking, suggesting that if Elijah had a thought to share, he shared it regardless of what other people were doing. Unlike Yonas and Hosein, Elijah offered interruption apologies. All of Guadalupe's math contributions were prompted by other people's actions; she made no math contributions while the group was silent, nor interrupted anyone. These data suggest that Guadalupe was not as comfortable as her peers initiating math contributions on her own. Participants' actions dominated Guadalupe's invitations for social contributions as well. However, she did make one social contribution that occurred during silence, suggesting she was more comfortable initiating social contributions than mathematical.

The majority of all contributions were prompted by participants' actions; participants included Ms. F (researcher), Ms. B (teacher) and Mr. K (student teacher) in addition to the four students. Ms. F was there the entire time. Ms. B visited the group once for 28 seconds, and Mr. K visited the group once for 33 seconds. Ms. B's and Mr. K's visits overlapped by 8 seconds. Figure 1 provides a closer look at the invitations that were attributed to *participant actions*. The figure contains two rectangles per student, one for math invitations (purple) and one for social invitations (blue). The top two rectangles show data for Yonas (bold outlined name). Orange arrows point away from Yonas representing the number of times Yonas's actions prompted a contribution from someone else. For example, the orange arrow from Yonas to Hosein in the top left rectangle shows that Yonas's actions prompted two math contributions from Hosein. Blue arrows point toward Yonas representing the number of times someone else's actions prompted a contribution from Yonas. For example, the blue arrow pointing from Hosein to Yonas shows that Hosein's actions prompted three of Yonas's math contributions. The thickness of arrows corresponds to the number of invitations, also shown as a number next to each arrow.

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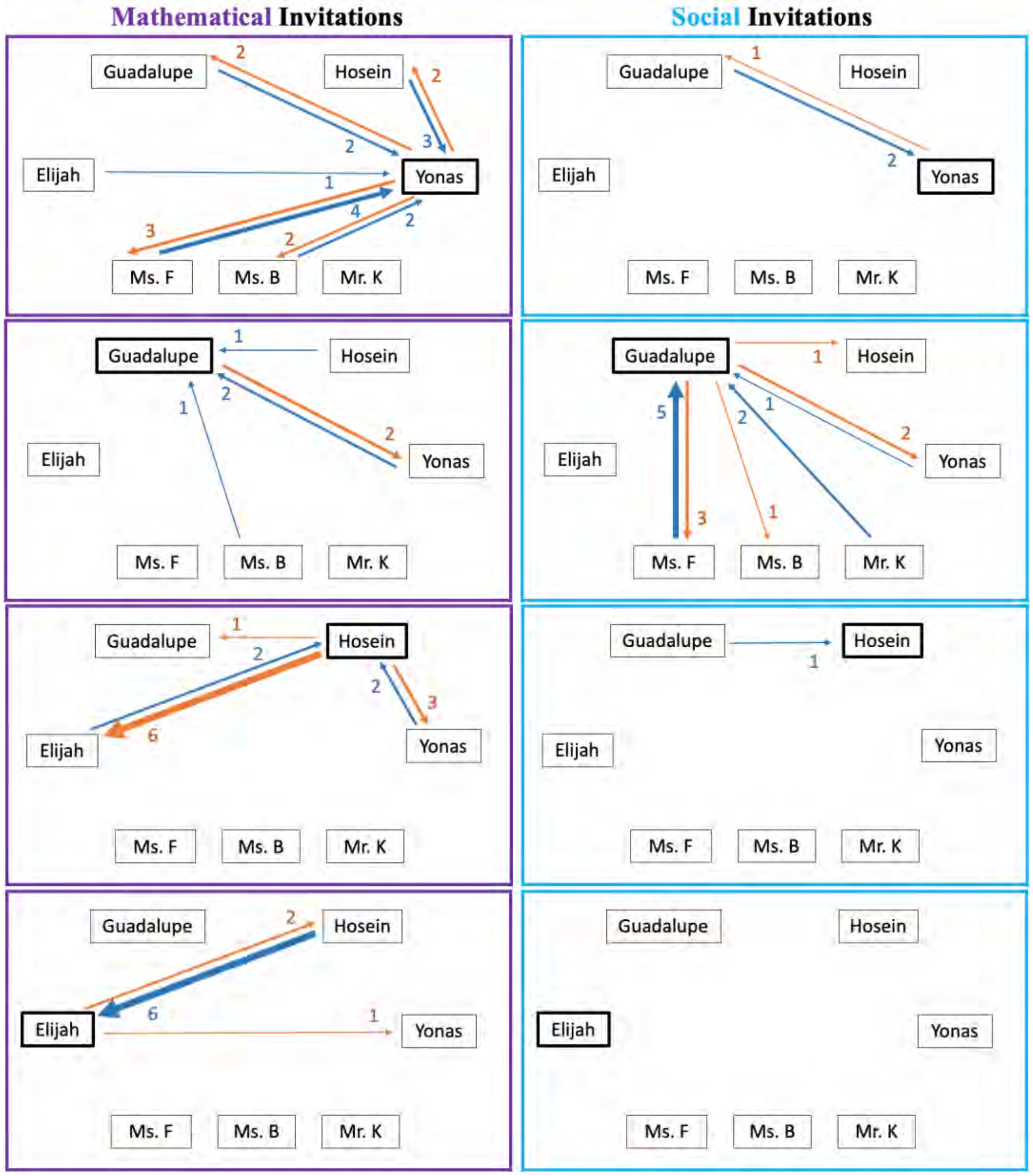

Figure 1: Participant Action Invitations *by* and *to* each Student

The top two rectangles show that Yonas connected through participant action invitations with everyone except Mr. K. Interactions between Yonas and others were relatively balanced and reciprocal; he interacted roughly the same amount with each person, and invitations *by* and *to* each person were relatively even. Elijah was an exception, with just one interaction with Yonas.

The next two rectangles, highlighting Guadalupe's interactions, show that she was connected to everyone except Elijah, and most of her interactions were social. In fact, Guadalupe was involved in *all* of the social contributions that took place during this task; she either made the contribution or her actions invited someone else to make a social contribution. Most of Guadalupe's social interactions involved adults, Ms. F in particular, and can be characterized as friendly, casual, and often humorous. For example, when Ms. F first entered the breakout room, Guadalupe greeted her with, "[Ms. F], oh my God! I get so excited!" *Ms. F's appearance in the group invited Guadalupe's contribution*. In response to Mr. K's sleepy appearance, Guadalupe

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teased, "[Mr. K], you look hecka bored." *Mr. K's appearance invited Guadalupe's contribution.* And, in response to Yonas's virtual whiteboard drawing, Guadalupe commented with sarcasm, "very sturdy looking ladder!" *Yonas's drawing invited Guadalupe's contribution.* Guadalupe made only four mathematical contributions, the fewest in the group. Her first math contribution was invited by Hosein's direct question, "[Guadalupe], what are you thinking about [the problem]?" The second contribution was an expression of agreement (i.e., "I agree with you,") in response to an explanation shared by Yonas just after Ms. B joined the room. The third contribution was invited by Ms. B's question to the group, "Are you guys saying yes or no?" Guadalupe's final mathematical contribution was a question she asked Yonas about what he was doing, invited by Yonas's virtual white board drawing.

The next row of rectangles shows that most of Hosein's interactions occurred with Yonas and Elijah. Two of Hosein's math contributions were prompted by Elijah's actions and two by Yonas's. The bottom two rectangles highlight the very limited scope of Elijah's interactions. Elijah interacted almost exclusively with Hosein with six of his contributions prompted by Hosein's actions. There were several back-and-forth math conversations between Hosein and Elijah which sometimes included Yonas peripherally, but never Guadalupe. One example occurred toward the end of the discussion when Hosein asked the group, "So, does that mean that the top falls twice as fast as the bottom?" *Silence invited Hosein's contribution.* Elijah responded right away, "Um. I don't think it's twice as fast because it's six verses eight." *Hosein's question invited Elijah's contribution.* Hosein explained further, "No, but it has to move an additional four on the bottom compared to the eight that it has to move at the top." *Elijah's comment invited Hosein's contribution.* Elijah contemplated Hosein's response, saying, "Hmm… True. Hmm… Interesting." *Hosein's comment invited Elijah's contribution.* This 2-person exchange illustrates the type of back-and-forth conversation Elijah engaged in with only Hosein.

Contribution Responses

Findings in this section address the question: *How did participants respond to each student's contributions?* Every contribution received a response from each person who was in the room at the time of the contribution, coded as positive, negative, or neutral based on participants' words and actions. Each contribution received 4-6 responses, depending on how many people were there. The four students and Ms. F were in the room the entire time. Ms. B and Mr. K were there for less than a minute each. Table 4 shows responses for each student's contributions.

Table 4: Responses to each Student's Contributions

	# of Mathematical		Positive		Negative		Neutral		# of Social		Positive		Negative		Neutral	
	Contributions	Responses	#	%	#	%	#	%	Contributions	Responses	#	%	#	%	#	%
Yonas	23	95	9	9%	3	3%	83	87%	2	9	5	56%	0	0%	4	44%
Guadalupe	4	18	0	0%	1	6%	17	94%	9	39	17	44%	0	0%	22	56%
Hosein	10	40	8	20%	2	5%	30	75%	1	5	4	80%	0	0%	1	20%
Elijah	10	40	0	0%	2	5%	38	95%	0	0	n/a	n/a	n/a	n/a	n/a	n/a

The majority of responses to math contributions were neutral for all four students. However, Yonas and Hosein received at least some positive responses to their math contributions (Yonas: 9 positive; Hosein: 8 positive), mostly in the form of verbal agreement (e.g., "yeah"). Neither Guadalupe nor Elijah received positive responses for any math contributions. On the other hand, all students received at least one negative response. When Yonas interrupted Guadalupe to share an idea, this counted as a negative response for Guadalupe. Negative responses also occurred when someone disagreed with an idea that was shared. For example, in the Elijah-Hosein conversation shared previously, Elijah responded negatively to Hosein's suggestion that the top of the ladder fell twice as fast as the bottom by disagreeing with Hosein. Then Hosein responded negatively to Elijah by further supporting his initial claim. Elijah was eventually convinced by Hosein's explanation and, consequently, responded positively to Hosein's final contribution.

Social contributions received more positive responses than math contributions, most coming in the form of smiles and laughs and many involving the adults. For example, shortly after Mr. K joined the room, Guadalupe accused him of looking "hecka bored." (See Figure 1 in Methods.) Guadalupe then admitted that she sometimes turns off her camera in class so she can lie in bed. She clarified by saying, "but not in this class. Never in this class." Smiling, Hosein responded, "Never." (This was Hosein's one and only social contribution.) Laughing, Yonas responded, "Jeez, does that actually happen?" Guadalupe, Hosein and Yonas all received positive responses to these social contributions from everyone except Elijah. There were big smiles and chuckles from Ms. F and Mr. K, but Elijah's expression did not change. In fact, Elijah did not smile once during the task. Even though Yonas and Hosein did not speak many social words, they indicated their support of Guadalupe's numerous social contributions through their frequent smiles.

Discussion

The goal of this study was to examine how opportunities for mathematical and social participation were constructed through acts of positioning during a small-group task. Students in the same classroom were positioned differently through their contributions. Yonas was positioned as a collaborative, talkative math contributor who shared his thinking freely, had easy access to the conversational floor (Erickson, 2004), and engaged in social interactions either directly with Guadalupe or indirectly by listening and smiling. Guadalupe was positioned as a jovial, caring, social contributor who brought smiles to participants' faces and shared math ideas when asked explicitly. Hosein was positioned as an inquisitive and polite math contributor who offered his own ideas and asked other people for theirs. Elijah was positioned as a deep-thinking math contributor who shared ideas and opinions freely and was oblivious to social norms.

These various positionings had implications for the opportunities students had to contribute to the group's collective learning experiences. Opportunities for mathematical and social participation looked different for different students. What counted as an *opportunity* for one student to participate did not count as a genuine *opportunity* for another. For example, silence in the breakout room constituted a clear opportunity for Yonas, Hosein, and Elijah to offer mathematical contributions, but not Guadalupe. If someone else was talking, that too counted as an opportunity for everyone except Guadalupe, though Yonas's and Hosein's interruption apologies suggest the opportunity was not as clear as it was for Elijah. Guadalupe's threshold for math contributions was much higher than it was for her peers; she needed an explicit invitation to share her mathematical ideas. However, Guadalupe's threshold for social participation was low; the appearance of an adult was enough to prompt a greeting or a light-hearted joke from her. The opposite was true for Elijah. Elijah's threshold for math contributions was the lowest of all four students, yet the threshold for social contributions was the highest. In fact, the threshold was so high that it was never reached in this episode. It is unclear what an opportunity for social participation might look like for Elijah since he did not participate in any social interactions.

Prior research shows that classroom participation is a function of the opportunities students have to participate, and opportunities are shaped by classroom contexts (e.g., how competence is constructed and how tasks are designed) (Gresalfi et al., 2009). However, to understand how opportunities for participation are differentially constructed within a single classroom, looking beyond classroom-level contextual factors is needed. This study suggests that constructing fair opportunities to participate requires: 1) conceptualizing opportunities for participation as deeply connected to students' positionings and developing identities in classroom communities, 2) acknowledging that what counts as an *opportunity* for one student to participate does not necessarily count as an *opportunity* for another, and 3) leveraging both mathematical and social contributions in creating equitable, supportive, and intellectually rich learning communities.

Working toward participatory equity – cultivating classrooms with *fair* (not necessarily the *same*) opportunities to participate (Esmonde, 2009; Secada, 1989) – requires taking into account that calculus classes are historically White, male-dominated spaces, in which females and racially minoritized students face additional barriers to participation (Leyva et. al., 2020). Opportunities to participate for Guadalupe, a woman of color, were undoubtedly different from those of her White and/or male peers. Exploring how racialized and gendered discourses shape students' opportunities to participate is an important direction for future research.

Acknowledgments

This work is supported by the National Science Foundation Graduate Research Fellowship Program. Opinions, findings, and conclusions or recommendations expressed in this material are those of the author and do not necessarily reflect the views of the National Science Foundation.

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