"I WATCHED AS HE PUT THINGS ON THE PAPER": A FEMINIST VIEW OF MATHEMATICAL DISCOURSE

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In this study we present results of a discourse analysis of the interactions between two partners, Uma and Sean, through a feminist lens. During roughly five hours of small group work in a teaching experiment, how each partner used language to position each other's thinking as mathematically significant and establish a collaborative environment varied dramatically. Specifically, Uma shouldered the burden of continuously working to maintain collaboration, oftentimes at the expense of having her thinking positioned as mathematically significant. On the other hand, Sean regularly offered little opportunity for Uma to engage openly with his thinking, which ultimately constrained Uma's opportunities to learn.

Keywords: classroom discourse; gender; attitudes, affect, and beliefs; equity, inclusion, and diversity

Numerous organizations invested in transforming mathematics education from predominately teacher-center towards student-centered advocate strongly for collaborative group work (e.g., Conference Board of the Mathematical Sciences, 2016; National Council of Teachers of Mathematics, 2014). Group work has been identified as an element of ambitious teaching in college calculus (Sonnert, Sadler, Sadler, & Bressoud, 2014) and has been associated with undergraduate students' positive attitudes towards learning mathematics (Sonnert et al., 2014). Research focusing on how mathematical ideas emerge as collective ways of reasoning during whole class and small group discussions has demonstrated the importance of interacting with peers' thinking for students' own learning (Rasmussen et al., 2020), and aligned mathematical development with the nature of collective mathematical argumentation during class discussions (e.g., Rasmussen, Wawro, & Zandieh, 2015). Additionally, language does much more than establish normative ways of reasoning about mathematics. In fact, discourse allows participants to enact and construct their identities (Gee, 2014; Langer-Osuna & Esmonde, 2017). Therefore, discourse occurring within small groups simultaneously offers students opportunities to learn mathematics and establish their identities. This study presents a discourse analysis of interactions between two students, Uma and Sean, to investigate how their use of language influences opportunities for learning.

Review of Literature

Mathematical Identity and Classroom Discourse

Over the last twenty years, mathematics education research has moved beyond "gap gazing," (Gutierrez, 2008) at static pictures of inequity, and toward research on the role of identity in teaching and learning mathematics. A variety of perspectives on identity formation have arisen, each emphasizing how learning in classrooms goes beyond understanding new concepts. Students also learn who they are and what they can and cannot do "with respect to the norms, practices, and modes of interaction" (Bishop, 2012, p. 36). Students' identities are "dynamically negotiated," representing a synthesis of who they are and who they have learned to be through interactions with others (Bishop, 2012, p. 38). Researchers have found the study of how students enact their identity at the microlevel, through classroom discourse, to elucidate explanations for the variability in mathematical identities within the same classroom.

Building on the framework proposed by Gee (2014), alongside Sfard and Prusak (2005), mathematics education researchers have used classroom discourse as a window into the formation and enactment of students' identities. Every instance of discourse in a mathematics classroom affords students the opportunity to negotiate their identities and respective social positions (Davies & Harre, 2001; Gee, 2014; Sfard, 2001; Wetherell, 2001). Early research on discourse focused on differences in students' desires when participating in group collaborations, finding that girls preferred to work cooperatively in groups, whereas boys "disliked working in groups because they felt it slowed them down" (Boaler, 1997, p. 297).

Langer-Osuna (2011) and Bishop (2012) shifted these conversations to focus on how students used language to position each other. Bishop (2012) described discourse between two students, Bonnie and Teri, and showed how Teri enacted the identity of the mathematical expert—speaking with authority and controlling activity and the uptake of ideas. Whereas Bonnie's discursive actions provided a window into the identity she inhabited and, in fact, helped to author—"dependent, mathematically helpless, and, at times, unknowledgeable" (Bishop, 2012, p. 57). Meanwhile, Langer-Osuna (2011) analyzed discourse to map how two students, acting as leaders in the same group, "developed opposite trajectories of identity" (p. 222). Brianna, originally publicly positioned by her teacher as an example of strong leadership, saw these same qualities positioned as inappropriate by her group. Whereas, Kofi, also positioned as knowledgeable but who was initially unengaged in the group's activities, found himself positioned as an authority figure by his group. Thus, discourse enables participants to establish and enact mathematical identities and also works to position members with (or without) power and authority.

Power & Authority in the Mathematics Classroom

Research on student interactions during small group problem solving has further demonstrated how students' mathematical identities, power, and authority can influence students' opportunities to learn (Chohen, Lotan & Catanzarite, 1990; King, 1993). Group collaborations fall prey to issues of status – the distribution of power among peers. Langer-Osuna and colleagues have documented how power and authority is negotiated among groups of students and is directly connected with how responsibilities for shared work are distributed (Engle et al., 2014; Langer-Osuna, 2016). Students as young as fifth grade have been seen to compete for *intellectual* and *directive* authority, which are heavily influential in determining whose solution strategies are used, whose ideas are assumed to be mathematically correct, and how effort is distributed among partners (Langer-Osuna, 2016). Johnson (2002) states that fights over who gets to speak and whose words are recognized are indicative of power and status.

Historically, male students have been positioned with power in mathematics classrooms (Webb & Kenderski, 1985; Wilkinson, Lindow & Chiang, 1985). Forgasz and Leder (1996) observed two boys refusing to work with their female group members when collaborating on a project with a "female-stereotyped context." Instead, the boys "used sexist language and taunted the two girls" (p. 163), insulting them while the girls completed the project entirely on their own. Jill voiced her disdain for the boys' behavior yet voiced how she and Cara didn't have any recourse— "If we didn't do it, it wouldn't get done" (p. 165).

These chiding remarks by group members took on a different flavor with Brianna (Bishop, 2012), who took on an early leadership role in her group. Less than halfway through the project, however, "group members increasingly positioned Brianna as bossy, claiming that Brianna was overstepping her authority" (p. 212). Two boys, repeatedly interrupted Brianna and scolded her for "being bossy," positioning themselves as a unified front against Brianna's bossiness. While the boys assaulted Brianna's leadership with criticism, they actively positioned Kofi as the group's leader, asserting his ideas deserved attention and seeking out help from Kofi. The leader-related utterances from Kofi were taken up by the group over twice as often as Brianna's, and his utterances were ignored or rejected nearly 25% less often than Brianna's.

These studies offer two perspectives for how students' negotiated identities go beyond the social interactions in the day-to-day classroom. Rather, student's identities also depend on the broader context of a student's life experiences (Gee, 2014; Wenger, 1998) and society's expectations for who they are and how they behave. Society grants students who are members of certain social categories with the right to hold positions of power over others. For decades we have seen research comment on how women—expected to be polite, accommodating, and reassuring—are not afforded positions of power in mathematics classrooms. Discourse has allowed us to see how these subservient positions manifest in classrooms, where women and girls do not have access to the conversational floor, are not able to decide what is correct, and are not seen to contribute meritorious ideas.

Theoretical Framework: Feminist Theory

Boaler (1997) admonished mathematics education as a discipline to "stop blaming girls for the underachievement and non-participation caused by the educational system forced upon them" (p. 304). The root of this underachievement and non-participation, however, potentially lies outside the educational system. The goal in mathematics education is for every student to have access to the resources and opportunities to be successful (NCTM, 2000). However, if discourse is viewed as a resource, then Jill, Cara (Forgasz & Leder, 1996), and Brianna (Bishop, 2012) exhibited pervasive differences in their discursive opportunities.

The gendered macroaggressions Brianna (Bishop, 2012) faced caused her to disengage from her group's mathematical activity and disassociate herself from her ambitious mathematical identity (Bishop, 2012). Villain (1998) argues that experiences such as those seen by Jill and Cara (Forgasz & Leder, 1996)—having their contributions ignored—implicitly conveys the message that their ideas have lesser value. Researchers have discussed these inequitable discursive opportunities as issues of power and authority (Langer-Osuna, 2016), but this research has not named these actions for what they are—*oppression*. A feminist standpoint, however, demands a commitment to understanding and challenging systems of oppression (Crasnow, 2014; Harding, 2004; Intemann, 2010; Intemann, 2016; Wylie, 2003). Adopting a feminist standpoint requires "studying from the margins out," (Intemann, 2016, p. 269) to reveal how power structures shape and limit the scientific phenomena under investigation.

This research expands these political discussions to focus on how discursive patterns between two undergraduate students positioned one student's thinking as significant and restricted another student's opportunities to learn.

Methods

The purpose of this study is to investigate the learning opportunities afforded to two students, Uma and Sean, while they solved problems during a small-scaled teaching experiment (Cobb., 2002). In particular, we pay specific attention to how the students used language and actions to, (1) position each other's thinking as significant, and (2) establish a collaborative environment. Each of these "building tasks" (Gee, 2014) are accomplished through discourse and allow us to understand the learning opportunities afforded to Uma, Sean and their group as a collective.

Setting and Participants

Uma and Sean were among six students participating in a small-scaled teaching experiment covering concepts of logarithms. The experiment consisted of five sessions each lasting one hour. Uma and Sean elected to work with each other. The two did not know each other prior to the experiment. Uma, a traditionally aged white women, had recently changed her major to secondary mathematics education. Sean, a non-traditionally aged white man, had returned to school to major in secondary mathematics education after a military career.

Data Collection and Analysis

Data collected for this study include recordings from the teaching sessions and individual semi-structured recall interviews. Interviews took place after the teaching experiment.

To analyze the discourse between Uma and Sean, we first watched the recordings from the sessions and identified *meaningful interactions*, which we define as an exchange of one or many talk-turns around a common on-task topic, idea or subject. Meaningful interactions may contain intervals of silence as long as subsequent talk-turns continue with the same subject and no changes to conversants occur. We considered instances when the teacher-researcher joined or left the conversation to constitute new interactions. Then, we transcribed all meaningful interactions and coded each conversant's use of language with verbs (e.g., revoicing, clarifying, explaining). Then, we analyzed the groups of codes emerging in the meaningful interactions to characterize how students positioned each other's mathematical thinking as significant, and whether their use of language was open or closed to collaboration. For example, a student asking, "Before, you were thinking..., do you think that still applies?" is using language to revoice their partner's previous mathematical thinking, positioning it as significant, and is also inviting collaboration. We also noted whether Uma or Sean shared ideas or strategies in each interaction.

Participants were shown three clips during the recall interviews. The first clip depicted an interaction where the interviewee had expressed either a high- or low-point in their engagement (see Williams et al., 2020). The second clip depicted the interviewee sharing a mathematical idea, and the third clip depicted an interaction where Uma shared a potentially meaningful mathematical idea that was not pursued on Sean's authority. We judged Uma's contribution to be *potentially meaningful* because it could have led to a solution to the problems being solved based on our evaluation. The first two clips were unique to each student. The third clip was the same. We use interview transcripts as evidence to support our claims from the discourse analysis.

Results and Discussion

Uma and Sean participated in 67 meaningful interactions while working together during the teaching experiment. Uma shared her thinking or a solution strategy in 20 interactions, while Sean presented his thinking or strategy in 54 interactions. From these interactions, Sean positioned Uma's thinking as significant 6 times, compared to the 38 instances in which Uma positioned Sean's thinking as significant. The common clip presented to both students during their recall interviews emerged as an interaction marking a shift in Uma's behavior while working with Sean. In what follows, we describe the progression of Uma's use of language for accomplishing the building tasks before, during, and after clip 3, as compared to Sean's.

Prior to clip 3, Uma was much more forthcoming in sharing her own mathematical ideas or strategies for solving problems with Sean, even though she self-described having low confidence stemming from how long it had been since she studied logarithms. Uma would share her thoughts without solicitation from Sean, and would respond to Sean with questions, even when presenting an argument for her own thinking. These uses of language are exemplified in the following interaction, which took place half-way through the first teaching session when students were attempting to create a timeline that accurately positioned a set of events (note, we use dashes in the transcripts to indicate when a student is cutoff or stops speaking abruptly).

Sean: So, I kinda ran out of room here, but I just went 10 to the 10th, 10 to the 9th... [pointing to his paper and turning to Uma] and then will fit those within there.
Uma: Oh ok! And then we'll fit them. Yeah [both work independently] … [Looking at Sean's paper, thinking aloud] 10 to the 6th
Sean: Yep, 10 to the 5th, and then I'm going to start my line. Over here, I'm actually going to extend it on- [continuing to work on his paper]
Uma: [9 seconds, looking at Sean's paper] and then you're adding a little bit more?
Sean: Mmhmm [7 seconds] Well, and that's turning into a scale that I recognize [bobbing, smiling slightly, looking over his glasses at Uma].
Uma: Yeah, so then that's- it goes to 10 to the 4th and then that's going to be 10 to the 3rd, and then to the 2nd (?) [looking at Sean]
Sean: Yep. And then I just went on out to-
Uma: 10 to the 0, yeah to make it easier [4 seconds]. So then, "Now" falls in at the 0 mark, right? Right? Would that be where we have "Now?"---
Sean: That's "Now," yep [working on his own paper]
Uma: [5 seconds] and then 10 to the 2nd is 100, right?
Sean: Yeah, so you want to kinda like- [continuing to work on his paper]
Uma: So then you have- [working on her own paper]
Sean: So if you wanna like- [7 seconds] the difference from here is actually 900 years, right.
Uma: Yeah, but then with each one the years are going to be more [gesturing "expanding" with her hands]
Sean: Yep. Yep.
Uma: Yeah, that's what I was thinking. I was like- because 500 is going to be- this is 1000, so your 500 is kinda going to be like half-way, right?
Sean: Yeah [slowly and hesitant]
Uma: it should be like here, 500, and then this will be 1000

This interaction begins when Sean states how he is creating his timeline using "eras" based on powers of 10. Uma positions this approach as signification by agreeing with the approach, revoicing his thinking (e.g., "10 to the 0 to make it easier..."), asking clarifying questions, and implementing his approach on her own paper. Uma's use of clarifying questions and posing her argument about where 500 should be positioned on the timeline as a question work to establish an open collaboration between the two students. Alternatively, Sean does not position Uma's thinking about where to position 500 as significant (which he disagrees with in a later interaction), nor does he elect to have a conversation about her suggestion to achieve consensus. Instead, Sean's responses are frequently short acknowledgements ("Mmhmm") that are closed to further collaboration. In fact, during his interview, Sean explained, "I don't think we were working together, we agreed on things, but I don't think we were truly working in unison."

Sean's limited attention towards Uma's mathematical thinking and frequently closed use of language persisted throughout the teaching experiment. In some interactions, Sean would elicit Uma's thinking vaguely—e.g., "What are you thinking?"—while in others Sean would invite Uma to read the next prompt, locate events on the problem sheet, or "unvite" Uma as a way to work independently—e.g., "we're going to do the math to see what it actually looks like, right?". However, Sean's use of language was not exclusively closed towards collaboration. Sean would initiate interactions by inviting Uma to share her thinking, or present his own thinking as an argument (i.e., Toulmin, 1963). Presenting an argument, over stating claims without evidence, is considered an open form of discourse because of the benefits to engaging with the reasoning of others (Rasmussen et al., 2020). In total, Sean's use of language was open to collaboration in 27 interactions and closed in 37, where it is possible for both to occur in the same interaction. Language that functions to open interactions for collaboration versus that which closed interactions was one primary difference in the discourse between Uma and Sean. Uma never used language that closed collaborations, while Sean's language was more closed than open.

The patterns of open and closed uses of language between the two students did not change much throughout the teaching experiment. However, Uma's willingness to share her thinking or solution strategies changed dramatically after clip 3, which took place as the last interaction from session 2. Leading up to this interaction, Uma and Sean were discussing a prompt designed to have students compare two large values, represented as events on a timeline constructed with an exponential scale with base 2. Uma and Sean were discussing the prompt, "Consider events, A which would be positioned at 16.005 and B which would be at 18.013. Which event took place longer ago and by how much? Explain."

Uma: [reading the prompt] Which event took place longer ago and by how much? So, did that just mean that the one point is going to be over here and the other point is going to be over here? Is that what that-

Sean: [looking back and forth between papers] Yep. Yep.

Uma: [quietly] So, B... and this is A. It says, which one of these took place longer ago. I mean, it would just be B, right?

Sean: It would be B, yep.

Uma: And that's just because it's farther back on the timeline.

Sean: [nodding, using his calculator] Yep. And then it's asking by how much.

Uma: So, then you'd have- you would just subtract 18- [gets quite]

Sean: [11 seconds] So that would give us the, the- [using his calculator] I don't know if there's a simpler way of doing that... [4 seconds]. So about 199,000 years. Does that seem right?

Uma: I think- Does it- so I'm just trying to remember like with exponents, can you, if it had the same like number, you can- can you take- so, like if we were to subtract because what I had done- because if you had subtracted the one and then the other one, and if you were to put 2 to the power of that (?)

Sean: So by inspection that's going to be-

Uma: be a little bit bigger, right?

Sean: be very, very small. Because that's going to be almost 4. Right, because 2 squared. But I think you're on to something. There's probably a relationship there. Um- [working on his own paper]

Uma: [40 seconds, quietly thinking aloud, working on her own paper] 2 to the 18[.013] minus 2 to the...

At the end of this interaction, Uma can be heard implementing Sean's subtraction approach for determining the amount of time between events A and B from the prompt, which takes place after she presents an argument for using a multiplicative approach that relies on properties of exponents. Implementing Sean's strategy and foregoing her own positions Sean's thinking as significant. Alternatively, Sean does not position Uma's thinking as significant in this interaction. In fact, there are two instances when Uma presents an argument (i.e., for event B taking place longer ago, and for how to compare the events using exponents), where Sean's responses are closed. Sean indicates agreement with Uma's first argument in a one-word response. Then, after Uma's second argument, Sean counterargues for why her response is different from his, and ends the interaction stating, "... but you're on to something..." while proceeding to work on his own paper. Sean's limited willingness to further consider Uma's approach while simultaneously comparing her solution to his own suggests he is positioning his own thinking as more significant than Uma's. Additionally, that Uma waited for 40 seconds, looking at Sean, before implementing his strategy may suggest she wished for more discussion.

Prior to and including the interaction from clip 3, Uma shared her thinking in 12 out of 27 meaningful interactions. Sean positioned Uma's thinking as significant in 4 of these instances. Following the interaction from clip 3, Uma only shared her thinking in 7 out of 40 interactions. Also, Uma adapts the way she positions Sean's thinking as significant in future interactions. Prior to clip 3, Uma would agree with, revoice, and implement Sean's thinking as a way of positioning his thinking as significant. Following clip 3, Uma also routinely invites Sean to collaborate with her by posing questions that also revoice his thinking. In other words, Uma found that Sean was a more willing collaborator when she initiated interactions with his thinking. For example, Uma would ask questions such as those in this interaction from the third session.

Uma: Well, it said that each segment is equal, right? So you're saying that this part [pointing to Sean's paper] is the same amount of space as this part, right?
Sean: I think from here there is about the same as there.
Uma: Yeah, okay, so now the question is, 'when you take the overlapped time, does this still preserve the same amount?'
Sean: As that 10 to 1? That is the question. I don't think that it is.
Uma: Mmhmm. Do you have any thoughts leaning you more towards why not?
Sean: [15 seconds] if we graphed them longer, we would end up with something like that. Um, we're saying then that is equal with that, or this is 10 times that, but I think-
Uma: that overlap takes away from it being able to be 10 times that, right?
Sean: Yeah, I just don't know how to- I guess here's what I would say. We know that if this were true, then shouldn't I be able to slide it a little bit further and a little bit further, and then I would have them on top of each other, and they are clearly not 10 to 1 then. You know what I mean? If I keep overlapping more and more, then they become the same time period. So, I don't--- any overlapping, I think is-
Uma: it conflicts, I guess. Yeah, that's a good way to-
Sean: does that make sense?
Uma: Yeah, that does make sense. What do you think about the overlapping? Do they still have a relationship similar to what you were looking at before, or how do you even compare their relationships with the overlapping?
Sean: Well, I think we are subtracting exponents here.
Uma: Mmhmm, and then you'd be comparing from there (?)

From Uma's interview, we know that she valued working with Sean because, "if I was struggling on something, we could talk it out, and I could like go somewhere with it." However, when reflecting on clip 3, Uma also explained, "in that moment, I felt like I actually knew what was going on... and it actually start[ed] to make sense to me." In this way, the interaction from clip 3 emerged as pivotal in how Uma positioned Sean's thinking as mathematically significant and maintained a collaborative working environment. Moreover, Uma appears to have made a conscious decision to sacrifice being viewed as smart by Sean in favor of maintaining collaboration, which proved productive when she positioned Sean's thinking as significant.

Unfortunately, Uma's approach worked. Sean did not appear to value Uma's mathematical contributions, and reflected on this in his interview, "I kind of felt like I wasn't getting much from her." Sean also did not place the same value on working collaboratively as Uma. It is possible that Sean's assessment of Uma's mathematical ability influenced his use of language to position her thinking as significant (or not) and to establish a collaborative environment. However, as demonstrated subtly in the previous example, Sean also began using strategies that involved properties of exponents ("Well, I think we are subtracting exponents here."). In fact, by the end of the last session, Sean posed an argument almost identical to the one Uma shared in the clip 3 interaction. Sean also reflected on this when discussing clip 3 in his interview, "... she's probably contributing more than I gave her credit for."

Conclusion

The discourse patterns emerging between Uma and Sean showcase how Uma took on the responsibility of establishing and maintaining a collaborative environment at the expense of having her own mathematical thinking positioned as significant. We believe Uma made this choice consciously, based on her reflection during the discussion of clip 3 in her interview and in the clear change in her use of language in all subsequent interactions. Uma took on significant cognitive load by deciding whether to share her thinking or create a collaborate environment by constantly posing invitations to Sean. We can imagine how tiresome it must have been for Uma to seek collaboration in this way. In fact, Gholson & Martin (2019) suggest these tedious micro-confirmations "might be experienced as pain" (p. 400). Moreover, seeking out these micro-confirmations, required Uma to "fundamentally distrust her own thinking and intuition" (p. 401), which could have contributed to her sense of co-dependence on Sean. In fact, in the interview, Uma stated, "I was looking to Sean to set an example of what his thoughts were and where he was going...I was watching as he put things on the paper."

Critically, Sean positioned Uma's thinking as significant in six of the 20 times Uma shared her thinking. This is not to say that Uma's ideas were inferior to Sean's, rather Uma's suggestion during clip 3 ultimately became the group's concluding "solution," nearly three hours after Uma's posed the argument to Sean. These constant negations of Uma's thinking as significant could be considered a type of microaggression (Sue et al., 2007).

To be clear, Sean was not outwardly harmful to Uma. In fact, their interactions may appear as "typical" or benign when viewed individually or through a non-critical lens. However, this is precisely our concern. The "typical" gendered interactions students such as Uma, Brianna (Bishop, 2012), Jill, and Cara (Forgasz & Leder, 1996) experience are oppressive and limit their opportunities to learn. Strategies for combatting such oppression consist of establishing classroom norms and cultures that value all mathematical thinking from each and every student such as rough draft thinking (Jansen, 2020) and holding all students responsible for actively engaging with their classmates' thinking and how that thinking contributes to problem solving (e.g., Rasmussen et al., 2020). Moving forward, our future research will investigate classroom and small group norms that elevate all students.

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