STRUCTURED PARTICIPATION PROMOTES ACCESS AND ACCOUNTABILITY DURING COOPERATIVE LEARNING IN MATHEMATICS EDUCATION

Nicholas Kim
University of Tennessee - Knoxville
nkim2@vols.utk.edu

Frances K. Harper
University of Tennessee - Knoxville
francesharper@utk.edu

This study investigated how the use of structured participation, specifically group presentation roles, supported more equitable participation in doing and learning mathematics. We analyzed videos of two lessons focused on radius, diameter, circumference, and area of circles in which students worked in small groups in a STEM project-based geometry class. Students' mathematics learning was assessed by the teacher through a group presentation where students were assigned individual presentation roles. We identified themes related to access and participation in small group and whole class interactions during this problem-focused lesson and found nuanced differences in both access and participation when compared to students' typical involvement in the more common unit-wide project-based tasks. Findings provide insights into effective uses of structured participation for both group work and whole class interactions to support more equitable doing and learning of mathematics in high school classrooms.

Keywords: Equity and Diversity, Instructional Activities and Practices, High School Education, Geometry and Geometrical and Spatial Thinking

Over the past thirty years, reform efforts in mathematics education have advocated for a greater focus on sense making and explanation and justification (e.g., NCTM, 1989; NCTM, 2000; NCTM, 2014). As reforms have slowly infiltrated more and more mathematics classrooms, the exclusive use of traditional direct instruction strategies has diminished in favor of greater emphasis on peer-to-peer collaboration in small groups (e.g., Boaler, 2008) and whole class discussion (e.g., Smith & Stein, 2018). Cooperative learning strategies found in complex instruction still provide some of the most effective ways of ensuring that peer-to-peer interactions in small groups positively impact student achievement in mathematics for all levels of learners. One of the key principles of complex instruction is the delegation of mathematical authority from the teacher to students, and a common way of ensuring that every student has an opportunity to take on mathematical authority is through the assignment of roles that structure the participation of group members (e.g., facilitator, recorder). The premise of roles is for all students to have important work to contribute in their groups, without which the group cannot function. Cohen and Lotan (1997) found when students take responsibility for each other and encourage everyone to contribute equally to tasks by performing their respective roles, there is an increase in student success in terms of mathematical understanding, and Boaler (2008) found group roles helped promote relational equity within the mathematics classroom. Boaler describes relational equity as "relations that include students treating each other with respect and considering different viewpoints fairly" (p. 168).

Langer-Osuna (2011), as well as Herrenkohl and Guerra (1998), found group roles served as one means of structuring student participation. Structuring participation increases the likelihood that students become positioned as competent, mathematical authorities. Students positioned with authority participate frequently in small groups and are able to gain access to and hold the floor, are able to decide what is correct, are seen as contributing meritorious ideas, and become influential in student-led discussions (Cohen & Lotan, 1995; Engle, Langer-Osuna, & McKinney de Royston, 2008; Inglis & Meja-Ramos, 2009). Erickson and Schultz (1997) defined participation structures as interactionally marked ways of speaking and listening, getting and holding the floor, and leading and following. In complex instruction, roles are typically designed to structure small group interactions, which are not specific to the mathematics work, but instead structure how the group cooperates (i.e., facilitator, not "grapher") (Cohen, 1994). This study builds on prior investigations of how the assignment of roles for working in small groups can promote access to mathematical understanding typically reserved for higher-achieving students who take over group assignments. We extend this work by exploring a non-traditional approach to role assignment and structure, namely assigning roles that structure how group members will present their mathematics work in a whole class setting. We considered how these presentation roles influenced more equitable access and participation among group members in both the small group and whole class settings. We theorized that, while providing access to mathematics for every learner, presentation roles might also provide teachers more ways to monitor student accountability. Thus, we aimed to investigate whether group presentation roles increased student participation differently than traditional group roles such as leader, time keeper, and materials manager for students who historically let others dominate group work activities.

Theoretical Framework

We draw on *figured worlds* as the theoretical basis for this study. People use figured worlds as a way to interpret particular actor and actions. These "worlds" are socially, culturally, and politically constructed and provide a way to "figure out" the significance of certain acts or the value of particular outcomes (Holland, Lachicotte Jr., Skinner, & Cain, 1998). As various factors (e.g., actors, actions, social/cultural/political forces) come together and relate to each other in different ways, *storylines* emerge that provide a taken-for-granted sequence of events for making meaning of actors, acts, and events (Holland et al., 1998).

For example, a possible storyline for collaborative projects in the mathematics classroom might be: "At the beginning of a project, one student takes the lead." Students take this action for granted, but depending on who takes the lead, students make sense of that action differently. If a boy takes the lead, he is likely positioned as smart, whereas a girl is likely positioned as bossy for similar actions (Langer-Osuna, 2011). The identities of 'smart' and 'bossy' are enacted by students and assigned by their peers based on specific classroom expectations for and interpretations of actors and actions, which are in turn are influenced by broader social, cultural, and political interpretations of gender identities.

In this way, the storylines constructed through figured worlds provide the context for what counts as mathematical engagement and for how students make sense of themselves as successful or not in relation to that engagement. In other words, students' mathematics identities are shaped as they come to see themselves and are seen by others as mathematically capable (or not) in relation to storylines (Horn, 2008). We use storylines to operationalize how students negotiated (i.e., took up, resisted, or shifted) mathematics identities in one cooperative task.

Research Design and Methods

This study was taken from a subset of data from a larger study that reviewed how students took up, negotiated, shifted, or challenged an innovative mathematics teaching approach using STEM project-based learning across an academic year (Harper, 2017). The study took place at a STEM-themed magnet school, in a low-income area of a small Midwestern city, whose mission emphasizes technology-driven project-based learning. The study took place in one ninth grade geometry classroom which consisted of 16 consented research participants. There were six males (4 white, 1 Black, 1 Latino) and ten females (9 Black, 1 Asian American). The teacher participant is a White woman who was in her fourth year of teaching. She and the second author collaborated on various projects focused on equity and social justice in mathematics education for three years, and the teacher frequently attended various professional developments on technology and equitable collaboration. The study will narrow in on one focus group of three females: Rosy, an Asian American student with high status; Carley, a Black student with high status; and Monique, a Black student with low status. We characterize students based on status rather than achievement because the construct of status recognizes that abilities in mathematics are socially constructed rather than cognitively fixed. Status is an idea commonly used in complex instruction to describe the social ordering of individuals based on perceived academic ability and social standing, where everyone agrees it is better to have a higher status (Cohen, 1994). Status can change in moment-to-moment interactions (Wood, 2013), but overarching perceptions of status influence how students describe themselves and others as "good at math" and "not good at math" in more rigid ways.

Focus Lesson Overview

Across two days, students worked in groups of three on radius, diameter, circumference, and area circle problems. The assignment was not part of a larger project, as was typical in this classroom. Instead the lesson involved problem-based learning around seemingly straightforward procedural problems through collaborative group work. The assignment consisted of twelve total circle problems, divided into four groups so that each group was responsible for presenting two or three assigned problems. Instead of the typical group roles used in complex instruction, such as facilitator, materials manager, or time keeper, to maintain accountability, the teacher assigned presentation roles for the whole class presentation to encourage engagement in the activity and accountability for individual learning in small groups. The three presentation roles were: (1) explainer, (2) question answerer, and (3) connector. The explainer was responsible for the initial explanation of the three problems; the question answerer was the only person who could respond to teacher and peer questions after or during the explainer's presentation; and the connector had to note similarities and differences to other problems presented by other groups to reinforce the big ideas of the assignment (i.e., conceptual connections and relationships across radius, diameter, circumference, and area of circles). During the first day, students worked on agreeing upon solutions to their assigned problems and preparing for their presentation. The students used a large poster board to present their work to the whole class at the end of the first day and into the second day.

Data Analysis

The first author created detailed descriptions of the actions, emotions, and body language in videos alongside a rough transcription of what the teacher and students said across two days in which the mathematics task was enacted. We analyzed this summary of the video in Nvivo (a qualitative analysis tool) by creating codes based on the strong theoretical basis of complex instruction (e.g., status, roles) (Yin, 2009). We identified initial codes independently and then compared preliminary analyses to arrive at final codes, which the first author confirmed by applying to the video and paying attention to exactly what was said along with actions, emotions, and body language. Next, we used the final codes and references to coded instances in the video of classroom observations to continue to refine themes about who and what was granted agency in the doing and learning of mathematics. These themes helped us to identify broader storylines at play during the lesson, based on talk, gestures, actions, etc., that were collectively constructed by and guided interactions among the focus group members, the teacher, and other students in the mathematics classroom figured world. For more information on how figured worlds guided analyses in the larger study, see Harper (2017).

Findings

In this section, we present our findings as the storylines that were collectively constructed by and guided interactions among the focus group members, teacher, and other students in this particular lesson. We provide illustrative evidence of group interactions and talk that show how we came to identify each storyline. These storylines shed light on how access and participation were negotiated among group members and the teacher in both small group and whole class settings by showing who and what was granted agency in the doing and learning of mathematics. More specifically, our findings show a dominant storyline of inequitable participation and access and a momentary, emerging storyline that shows promise for more equitable access and participation following the introduction of presentation roles that influenced who and what was granted agency. The first two storylines were collectively constructed as the group members worked in a small group setting, and the third storyline was collectively constructed during the group's whole class presentation.

Dominant Storyline (Before Teacher assigned presentation roles): Only the "good" Mathematics Students Do the Mathematical Work of the Task

Rosy and Carley, as the students with high status in the group, did the majority of the mathematical work while Monique, as the student with low status in the group, did not engage with the group or the mathematics. Monique's attention was not on any relevant mathematical content, but rather her laptop where she engaged in social media and computer games even after instructed by the teacher to put away all irrelevant technology. Rosy and Carley did not try to engage or encourage Monique to participate as they had become accustomed to Monique's lack of engagement in the class through previous group activities (see Harper, 2017 for evidence of this claim about how Monique was positioned in storylines outside of this specific lesson). After Rosy and Carley discussed how to solve their assigned problems, they shifted their attention to writing on the poster board for the presentation at the end of class. At this time, Monique put her laptop away to make room for the poster board at their tables. Monique began watching Carley telling Rosy what to write on the poster board for each assigned problem, but it was unclear if she was trying to understand the solutions. Rosy and Carley were granted agency for the mathematical work as they were considered high-status students. Being a high-status or "good" mathematics student did not require including other students in the mathematical work of the group.

Emergent Storyline (After Teacher Assigned Presentation Roles): "Good" Mathematics Students Include Other Students in the Mathematical Work

The teacher introduced presentation roles and assigned them to each student after allowing the groups to work for 15 minutes. Rosy and Carley maintained ownership over the mathematical work and direction of the group, based on their status as "good" mathematics students. For example, Rosy expressed how she wanted to do multiple roles because she frequently answered teacher and student questions during individual and whole class interactions:

> Rosy: Shoot, why do we got to all have different jobs, cause like I want to be the explainer and the question answer.

Otten, S., Candela, A. G., de Araujo, Z., Haines, C., & Munter, C. (2019). *Proceedings of the forty-first annual meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education*. St Louis, MO: University of Missouri.

Teacher: (*After overhearing Rosy's comment*) Well you got to delegate some work out, but you guys only have #9 and #11 when you go up there.

After the teacher's insistence that all group members play a role in the mathematical work of the whole class presentation, Carley and Rosy made a noticeable effort to include Monique and encourage her participation. Carley assigned roles to her group members after this short exchange between Rosy and the teacher (maintaining authority over the group's work). She assigned Rosy to be the explainer, and Rosy agreed. Carley then assigned Monique the position of question answerer. Carley took it upon herself to be the connector even though she was confused about the role and repeatedly questioned the teacher and her group members about the purpose of the role.

After roles were determined, Rosy made the first real effort to engage Monique with the mathematical work she and Carley had completed by asking, "What do you need to be the question answer?" Monique responded so softly that it was inaudible in the video. Rosy began to explain step-by-step how she and Carley solved each assigned problem, and she made additional efforts to ensure that Monique understood the mathematical work. Namely, Rosy provided additional information about circles, such as the relationship between radius and diameter, as she explained the steps:

Rosy to Monique: (*Carley is looking at her phone but also trying to listen to Rosy)* So, if they ask you a question… so basically, I am going to explain it but like you might have to re-explain it if they ask you a question. If they don't get it, you'll have to explain it again.

So, number 11 says find the radius. So, I said the purple one is radius, right? So that means the radius is half of this line, so the information they gave us is the diameter which is this part right here. We need to figure out radius, so if the radius is 4.8, we have to, we have to split that in half. Because half of the diameter is radius. So, half of 4.8 is 2.4. Okay so it's easy to divide the diameter by 2.

Number 9. So basically, we are finding the circumference of the circle. The circumference is all around the whole circle (*Rosy draws it*). Umm, the given information we have the area. The area is everything inside the whole entire circle. (*Rosy models it on paper again*) You know area right. (*Monique shakes her head yes*) Umm, so basically, we know the formula to find the area is pi times r squared and r stands for the radius. So basically, what we use, we took the area and divided it by pi because that's what we times it by... pi -r squared is the formula to find the area. We divided that by pi to cancel each other out."

Monique rarely spoke and mostly watched and listened to Rosy explaining each part of the problem. Although many might not consider this active engagement on Monique's part, this level of access to and participation in the mathematical work was a notable improvement when compared to her access and participation before the introduction of presentation roles. In both Carley's assignment of a role to each group member and Rosy's "teaching" of the mathematical work to Monique, we see both Carley and Rosy maintaining their status as "good" mathematics students who have authority over the work of the group. However, their actions following the teacher's introduction of presentation roles begin to shift what it means to be "good" mathematics students to include encouraging participation by others in the mathematical work of the group.

Dominant Storyline (During Whole Class Presentation): Only the "Good" Mathematics Students Do the Mathematical Work of the Task

During the whole class presentation, Rosy and Carley enacted their presentation roles as explainer and connector, respectively. Rosy began the presentation with an explanation of problem 9 and then problem 11 when prompted by the teacher:

> Teacher: Okay, what about #11?
> Rosy: We had to find the radius of the circle which is the point in the middle to the side of the circle, but the only information given was the diameter which is one side of the circle to the other. And um so basically, that means the radius is half of the diameter. So, we had to divide the diameter in half. 4.8 divided by 2 is 2.4."

The teacher then asked Carley to make connections to other problems:

> Carley: [Our problem] was similar to all of these problems from 15 to 9.
> Teacher: How is it similar?
> Carley: Because they to do the square and division to get rid of the multiplication (Inaudible)…

These excerpts illustrate how the teacher encouraged both Rosy and Carley to explain further or in greater detail. Thus, both Carley and Rosy, as high-status students, were positioned as student capable of learning and doing mathematics. The teacher's and other classmate's positioning of Monique, however, was noticeably different when Monique enacted her role as question answerer.

> Teacher: Does anyone have any questions for this group?
> Student 1 from another group: Why did you guys use secondary colors [on your poster]?
> Teacher: Monique, do you have an answer for that?
> Monique: Because we just wanted to use them.
> Student 2 from another group: I have a question. Why did you have to find the radius on that problem?
> Rosy: It made it easier for us to calculate 2 pi r when we have r.

In our analyses of other group presentations, the teacher enforced the individual presentation roles for all group members. The above excerpt shows how the teacher's enforcement of the presentation roles changed when Monique engaged with her role. The initial question posed to Monique was a non-academic question in which the teacher required Monique to answer based on her opinion, not on her capability to learn or do mathematics. When another student posed the second question about finding the radius, Rosy immediately answered the question before Monique had a chance to answer. The teacher enforced the roles for all other students but allowed students with high status to take on the role for a student with low status in this instance. This excerpt illustrates the power of the dominant storyline that only "good" mathematics students do the mathematical work of the task and shows how the teacher and other students were complicit in positioning Monique as someone incapable of participating in that mathematical work.

Discussion and Conclusion

Much of the research on complex instruction at the secondary level in mathematics focuses on "master" teachers who are experienced with the pedagogical approach (e.g., Boaler & Staples, 2008) or contexts in which students experience complex instruction across the curriculum (e.g., Horn, 2008). This research extends what is known from previous studies by exploring one aspect of complex instruction within a classroom where the teacher is newer to using complex instruction and where complex instruction strategies are not reinforced across the curriculum by other teachers. Findings from such investigations are important because they can shed light on how the moment-by-moment negotiations that must happen among the teacher and students to shift who and what is given mathematical agency (e.g., Harper, 2019; Wood, 2013). Changes towards more equitable access and participation in mathematics do not happen instantaneously with the introduction of strategies such as structured roles for participation. Instead, these shifts are negotiated, resisted, and (hopefully) taken up over time, and this study contributions to our understanding of how such changes to access and participation may begin. In this final section, we identify and discuss two implications based on the findings presented here.

Pervasiveness of Inequitable Access and Participation

Both the first and third findings above illustrate how powerful and pervasive storylines that encourage inequitable access in and participation in mathematics learning and doing are. In small group work, Rosy and Carley took ownership of the task by discussing and solving their assigned problems, using appropriate terminology and formulas while demanding justification for each process. Unfortunately, Monique had little involvement with the discussion. During the whole group presentations, Monique seemed to encounter yet another missed opportunity for mathematical engagement. Interestingly, the teacher consistently enforced presentation roles for high-status students, and she pushed the high-status students such as Rosy and Carley for justification and more detailed mathematical explanations. She was less consistent with her enforcement of roles for student with low status. The teacher enforced Monique's role as question answerer for a non-academic question posed by her peers but then allowed Rosy to take over Monique's role when a mathematical question was asked. We might speculate as to why the teacher allowed Rosy to take over Monique's role. Perhaps the teacher worried that Monique may not know the answer, and she wanted to avoid calling her out as the question answerer for a mathematical problem. Perhaps the teacher was happy to see Monique participating more than she typically did and wanted to encourage her to feel safe participating in the future. The teacher's knowledge of her students likely played a part in her decision to allow Rosy to take over. Regardless of the teacher's exact rationale, however, one implication to consider is that we, as teacher educators and researchers, may need to better prepare teachers to navigate the gradual and complex shift towards more equitable access and participation. Recognizing how powerfully storylines that encourage inequitable access and participation might resist change may help teachers remain diligent in attempts to incorporate strategies such as structured roles more consistently.

Variety of Roles for Structured Participation

Findings from the emergent storyline show how, after presentation roles were introduced, Monique had the greatest access to and participation in doing and learning mathematics through the whole lesson. Although Carley and Rosy maintained most of the mathematical authority, Rosy used that authority to prepare Monique for her role as the question answerer. Rosy was motivated to engage Monique because she knew that Monique needed to understand the mathematical work in order to answer any questions that arose from the explanation. Monique made an effort to watch and listen to Rosy's explanation and subsequent discussions. Monique did not provide much of her own mathematical thinking, but she made the effort to understand her group's mathematical thinking. Interestingly, a role that was intended to promote more equitable participation in whole class presentations provided greater access and participation in the small group setting instead. This shows that participation structures such as presentation roles, which are not typically associated with complex instruction, might have a larger than intended effect by providing accountability across small group or whole class settings when those roles are enforced.

Although employing various types of structured roles for participation shows promise for increasing engagement, the findings here show that increased participation does not necessarily mean greater active engagement with the mathematics. Students may be motivated to participate more because they are assigned a specific role, but if those roles are not enforced by the teacher with fidelity then students may depend on their peers to do the heavy mathematical work. A combination of the assignment of group presentation roles with teacher enforcement of such might prove an effective way of using this particular structured participation format. If students know they will need to present to the whole class as individuals in a group assignment, they cannot hide completely behind high-status students. They will have to become experts in their problem to be prepared for various question types from peers or teacher. It is the role of the teacher to explain the roles extensively as well as enforcing the roles with the same rigor for every student.

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