

Networking Theories to Investigate Status and (In)equities in Small Group Proof Contexts

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Efforts have been made to study (in)equity in undergraduate mathematics education research. Across various fields, there is a foundation of work on how status impacts students' learning and participation in small groups as well as how differing patterns of interaction contribute to inequitable outcomes. This report contributes a networked theory for analyzing relationships between status and (in)equity in general. We argue that applying this methodology to proof-specific contexts has the potential to uncover how status hierarchies form in proof classrooms using group work components. We hope to promote conversations within the RUME community around taking actionable steps towards delegitimizing status hierarchies in proof classrooms.

Keywords: Status, Inequity, Small Group, Proof

Generally, increasing student-student interactions in classrooms changes the quality of interactions, creating more opportunities for societal narratives about who can do what kind of mathematics to influence who participates and how (Battey & McMichael, 2021). A dominant societal narrative is that 'doing mathematics' reflects 'doing masculinity' (Jaremus et al., 2020; Leyva et al., 2017; Mendick, 2006) and simultaneously privileges whiteness (Battey & Leyva, 2016; Martin, 2019) and Eurocentric perspectives (Rowlands & Carson, 2002). Scholars have argued that students who identify with the dominant culture of mathematics inherit this privileged status, particularly in advanced proof-oriented classrooms (Weber & Melhuish, 2022). The power that these narratives have can be corroborated by the fact that advanced courses are predominantly taught by (mostly white) men and the majority of students who take them are men (Blair et al. 2013). If a goal is to increase student-student interactions in these spaces (Saxe & Braddy 2015; the MAA Instructional Practices Guide, 2018), then it stands to reason that issues of inequities related to status and power must be considered.

Scholars have recently attended to status and power in proof-based contexts (e.g., Brown, 2018; Ellis & Alzaga Elizondo, 2023; Hicks et al. 2021). Adapting an authority framework, Hicks et al. (2021) explored how four students' mathematical authority was distributed while working on an abstract algebra task. They found discrepancies in authority relations and offered reasons why these discrepancies might have occurred, such as only some students authoring ideas in public spaces, students self-selecting to not participate, and assessing ideas to give or take away authority. Drawing on Shah and Lewis's (2019) work, Ellis and Alzaga Elizondo (2023) investigated how status attenuated/amplified (in)equities during small group work in an intro-to-proof course. Using relational and participatory equity as an analytic lens, they claimed that a 'less mathematically collaborative' episode exhibited a more balanced status relationship while a 'more collaborative' episode exhibited strained power relations. While intriguing, these claims could have been strengthened by a clearer theoretical connection between status, power, and inequity, which guided the empirical analysis of their data.

This report contributes a possible theoretical approach to empirically identify how status hierarchies form in small group interactions. That is, we claim that networking positioning theory (Harré & van Langenhove, 1999) with systemic functional linguistics (SFL; Halliday, 1978) may provide empirical evidence of discursive processes by which students attribute academic status to themselves and others. This approach may yield stronger claims regarding how inequities are attenuated/amplified in small groups (Shah & Lewis, 2019).

Background

In classrooms where students interact with each other regularly, issues related to status and positioning are more likely to occur (Cohen & Lotan, 2014; Esmonde, 2009b; Shah & Lewis, 2019). In general, ‘status’ refers to the idea that it is desirable to be in a higher position relative to another (Cohen et al., 1999; Ridgeway, 2018). For example, narratives around socioeconomic status allude to the idea that it is better to have more monetary capital than less, and people generally agree that is advantageous to be in a higher status position than a lower status position. In classroom contexts, academic and peer status greatly influence perceptions of where individuals fall along a status continuum (Cohen & Lotan, 2014). The former relates to perceptions of who is ‘smart’ or doing well in the class. The latter relates to perceptions of social standing (i.e., popularity, attractiveness). Then, ‘diffuse status characteristics’ refer to identity markers that are perceptible upon initial encounters with others, such as race (via skin color) or language use (via intonations or accents), gender expression, and certain forms of ability status. For our purposes, when we say “status” we mean academic status while acknowledging that peer and diffuse status characteristics influence attributions of academic ability or competency in proof classrooms.

Researchers studying student-student interactions during collaborative small group activities have made theoretical connections between status and positioning (Langer-Osuna, 2016; Esmonde, 2009a; Shah & Lewis, 2019). For example, Langer-Osuna (2016) argued that “students interactionally position themselves and one another with academic and social power that can affect collaborative mathematical work” (p. 108). To examine authority relations, they asserted that students who are positioned with more intellectual authority – that is, students positioned as valid sources of information directly related to the current task – accumulated more influence, and thus, academic status. In their coding scheme, influence was attributed to a student whenever their idea was “positioned as having become part of (or rejected from) the solution path” (p. 112). This aligns with our notion of influence as the combined result of being given opportunities to contribute that are subsequently evaluated positively by others.

An indirect link can be made between status and research on students’ participation in groups since identity markers, such as gender, have been shown to influence participation (Ernest et al. 2019; Langer-Osuna, 2011; Reinholz et al., 2022). For instance, Ernest et al. (2019) found that men and women participated at relatively similar rates in private group talk, yet men dominated the public space in class discussions. Likewise, investigating gender roles in small groups using mixed methods, Langer-Osuna (2011) showed how Brianna’s project-related conversation declined overtime and self-perception went from “good leadership” to “being bossy” while Kofi’s project-related conversation increased, and he perceived himself as the “smart” student in the group.

At the undergraduate level, quantitative studies have pointed to gendered disparities in performance on proof-based tasks. Johnson et al. (2020) reported findings that indicated men fairing significantly better in inquiry-oriented proof classes compared to men in traditional classes, while there were no significant differences in performance for women. Reinholz et al.

(2022) built on this analysis by studying participation patterns, finding that performance disparities could be attributed to women's participation rates. We argue that there is a need to provide qualitative explanations for such results, and one possible direction is to explore how status hierarchies are de/legitimated (Adams-Wiggins et al., 2020) in proof contexts where small group work occurs, such as in inquiry-oriented classrooms.

Networking Theories to Evidence Status Relations

This report contributes a possible theory to analyze student-student interactions mediated by discourse – conceptualized as language-in-action used to communicate meaning, including written, verbal, gestural, and other forms of communication. We contend that networking positioning theory with SFL may provide useful analytic tools to document how status hierarchies form in small group interactions. With such evidence as a guide, we argue that situations in which status hierarchies are legitimated likely amplify inequities, while situations where status hierarchies are delegitimated likely attenuate inequities, with *inequities* defined as situations that prevent access to resources needed for learning (Shah & Lewis, 2019). It is worth noting that because human interactions and power relations fluctuate based on available positions, no situation will ever be 'status-free' or fully 'equitable'.

Positioning Theory

Positioning theory explains the processes underlying how participants in an interaction attribute rights and obligations to themselves and others (Harré & van Langenhove, 1999; Harré, 2012). Relationships between communication acts (i.e., the meaning embedded in speech and other forms of communication) and storylines (i.e., accepted sociocultural repertoires for how to interact in a situation) are what give rise to available positions or 'rights and duties' (Herbel-Eisenmann et al., 2015). In an educational setting, for example, a traditionally accepted teacher-student storyline is one where teachers are the authority and students are obligated to do what the teacher says. Such a storyline may be evidenced in the communication acts between participants; perhaps the teacher issues a command to students (e.g., "Please get out your notebooks and a pencil") and students accept the obligation by getting out their notebooks and a pencil. In positioning theory, when communication acts and storylines work together to make rights and duties available to participants, there is always a choice to accept, negotiate, or reject the positioning. For example, in the teacher-student scenario, perhaps a student does not get out a notebook or pencil. This could be interpreted in multiple ways; maybe they do not have the materials with them or perhaps they are rejecting the command intentionally.

Broad narratives about mathematics and who is perceived to belong to mathematics culture can operate as storylines associated with mathematics classrooms that students are likely aware of. For instance, mathematics culture is widely perceived as Eurocentric, white, and dominated by men (Battey & Leyva, 2016; Jaremus et al., 2020; Leyva et al., 2017; Martin, 2019; Mendick, 2006; Rowlands & Carson, 2002), which positions students who identify with this culture with higher status in mathematical spaces relative to others. A problematic exception is that students are well aware of the societal narrative that Asians are "good at math," which perpetuates the "model minority myth" (Poon et al., 2015; Shah, 2017). This is problematic since it positions students in a place of higher status (i.e., gifted academically) while also excluding them from communities of other minority students along with associated supports for those communities (Ng et al., 2007; Suzuki, 2002).

In sum, positioning theory provides conceptual grounding for why (and how) status hierarchies form in small group interactions. A limitation is the conceptual vagueness around interpreting the meaning embedded in participants' communication acts and the possible storylines at play (Herbel-Eisenmann et al., 2015). Therefore, we bring in analytic tools from systemic functional linguistics to evidence how positions are created and maintained through participants' discourse.

Systemic Functional Linguistics (SFL)

Broadly, SFL offers a learning theory centered on language use, with language operating as a complex, dynamic, and context-based system (Halliday, 1978). Three metafunctions of language comprise SFL: *interpersonal*, *ideational*, and *textual*. The textual metafunction "manages the flow of information to make extended discourse coherent and cohesive" and the ideational metafunction "constructs ideas and experiences" (Gebhard & Accurso, 2020, p. 1029). The interpersonal metafunction represents socially constructed positions and power structures. In our methodology for studying how status operates to organize interactions in classrooms, we are centrally concerned with the interpersonal metafunction which is mediated by "tenor" choices – resources including (but not limited to) the use of mood systems.

Within the mood system, statements made evoke a declarative mood, questions asked evoke an interrogative mood, and commands issued evoke an imperative mood (Gebhard & Accurso, 2020). Gebhard and Accurso (2020) assert that within the interpersonal metafunction and mood system, textual analysis can evidence how statements, questions, and commands influence social structures and power dynamics, particularly in classroom interactions. For example, such an analysis can capture who has the right to speak versus who remains silent, "who uses statements to construct authoritative 'facts'; who asks questions and engages in negotiating meaning; who gives commands and how commands are taken up or resisted" (p. 1032). For our purposes, the textual artifacts analyzed are transcripts of students interacting during group work.

We argue that the interpersonal metafunction of SFL, including tenor resources such as the mood system, provides concrete evidence of power relations emerging and shifting during group interactions through discourse patterns. We conjecture that documenting these processes can evidence how status hierarchies form in interactions because *who* issues commands, uses statements to convey authoritative 'facts' and maintains the right to speak will likely be perceived as having higher status relative to others in the interaction.

Interaction Process Related to Status Formation

Through the interaction process of creating opportunities to contribute and evaluating contributions, certain students are positioned as having more influence (e.g., Langer-Osuna, 2016). Those who acquire more influence during the interaction will have higher relative status compared to others, ultimately legitimating or increasing status hierarchies within the group. In what follows, we describe this process in the context of proof.

Opportunities to contribute. When assessing *opportunities to contribute* among members of a small group, we examine instances in which the group encounters a problematic situation and consider group members' attempts to offer a resolution, the timing of these offerings, how these offerings are solicited by other group members, and the time and attention members have when responding. For example, a group may need to interpret an assumption when working together to develop a proof. A group member may ask, "Does anyone know what [term] means?" followed by wait time. Such a generic solicitation often confers an opportunity to contribute

upon the highest-status members of a group, who tend to experience the least psychological risk when offering a suggestion and will often be the first to respond. Alternatively, a member (or instructor) may ask a specific groupmate, “I remember you said something helpful about [term] before. Can you remind me what you said?” Depending on the relative status between the participants, this may elevate the academic status of the groupmate granted the opportunity to contribute, potentially countering the hierarchical effects of peer status and diffuse status characteristics.

Evaluations of contributions. Any contribution by a group member, unless interrupted by the end of a small-group activity, is implicitly or explicitly evaluated by the group. When analyzing *evaluations of contributions* from group members, we consider both explicit evaluations (immediate verbal and nonverbal responses to the contribution) by other members and implicit markers such as an attempt to reinforce or reconcile the contribution with other prior contributions, a follow-up question or suggestion building on the contribution, or a group moving on without appearing to give serious consideration to the idea suggested.

Students’ evaluations may have status implications when they appear to agree or disagree with a peer’s contribution. For example, when asked to provide a proof of a proposition about equivalence of two expressions involving set operations, a student in a group might suggest drawing a Venn diagram illustrating each sequence of set operations. Another group member, skeptical of the viability of this approach, might simply say, “[Instructor] said that a Venn diagram isn’t a proof,” implicitly dismissing the possibility that a diagram might support the group’s thinking. Alternatively, they might say, “Can you show how you would use a diagram for this problem?”, inviting the student to elaborate on their initial contribution. A third possibility is that a peer might ignore the Venn diagram suggestion entirely and say “We need to assume that x belongs to A and B but not C .” We posit that each of these interactions has different implications for the status of the group member who suggested the diagram, both as evidence of their academic status within the group and as potential incremental effect on the student’s status within the group and in the class.

Influence. When considering each group member’s *influence* in a proof-oriented context, we examine instances in which a group must make a decision about a strategy, validity of a claim or contribution, or about the group’s collective focus (such as a decision to move on to a different problem or task). In each such instance, we review group members’ verbal and nonverbal communication to determine: (1) whether group members seem to defer to a specific member or subset of the group when making the decision; (2) whether a member’s input into the decision is taken up by the group; and (3) whether a member suggests criteria or heuristics for decision-making that ultimately inform the group’s actions. As an example of the latter, consider an episode in which a group must prove that a sequence converges to a limit, and a student starts by writing the inequality $|a_n - L| < \epsilon$. At this point a peer might interject and say that this inequality is what the group must prove, and a proof is not allowed to begin with the statement to be proven. If this persuades the group to move away from this strategy, this would point to the peer’s influence over the group’s decision making. If on the other hand the student continues manipulating this inequality (perhaps as a strategy to discover a value of N corresponding to ϵ) and is able to enlist the group into helping, notwithstanding the peer’s objection, this might point to the first student’s influence. It is important to consider that the direction the group takes in this

scenario is not purely a function of how well each group member argues in favor of their strategy; it depends on the group's implicit judgment about each member's propensity to identify and validate potential strategies for developing the proof.

Example of Theory in Action

In this section, we demonstrate the analytic potential of the proposed networked theory. Ellis and Alzaga Elizondo (2023) previously analyzed the role of status in two small-group episodes using the constructs *opportunities to contribute*, *evaluations of contributions*, and *influence over group decisions*. The participants were students in an introduction-to-proofs course taught remotely over Zoom with the second author attending class each day (see Alzaga Elizondo, 2022). Alison, a white woman, became a focal participant since interactions in one episode with Lee (East Asian man) evidenced differing participation patterns compared to an episode with Justin (white man). Based on daily observations of class interactions (including virtual breakout rooms), Lee was perceived to have higher academic status relative to Alison. Both Lee and Justin also benefited from belonging to demographic groups that granted them higher academic status in mathematical spaces.

Questions Support Leveling Academic Status Positions

In the following exchange, Lee and Alison used a balanced combination of statements and questions as they worked on a shared Google doc to prove that group isomorphisms preserve inverses.

Lee: From here can I just jump to like, therefore e_2 - therefore $\phi(e_1)$ is the identity by definition or is that skipping some steps? (pause) [Question]

Alison: Hold on I'm thinking (pause) [Statement]

Alison: yeah I think that's good. [Statement]

Alison: (reads) "By definition of identity." So $\phi(e_1)$ must be the identity in-

Lee: Oh wait, but we're not saying for all H , we have to prove that that's all H . [Statement]

Alison: the identity- What do you mean all h ? [Question]

Alison: Oh for the identity for all h ? [Question]

Alison: But we've already proved that there is only one identity. [Statement]

Alison: Isn't that in the definition of identity? [Question]

Lee: Yeah, but like this is showing the identity for all these, some elements of H until we show- [Statement]

Lee: I guess we can use onto right? [Question]

Alison: Yeah. (nods affirmatively) Yeah, we probably have to use onto. [Statement]

Overall, the discursive move of asking questions to elicit evaluations of intellectual contributions functioned to level the perceived academic status between the pair. For instance, Lee, a relatively higher status student compared to Alison, started off the exchange with a question inviting Alison to evaluate his suggestion to "jump" to the desired conclusion. This attributed academic status to Alison as someone who had the right to validate mathematical ideas. Alison accepted this position by using a declarative statement that positively evaluated Lee's idea ("yeah I think that's good"). Further along, Lee began a talk turn with a statement declaring what he knew about a particular line in their proof, saying "this is showing the identity for all these." He then used a question to ask Alison how they should approach a refinement, saying "I guess we can use onto right?" Again, this attributed academic status to Alison by positioning her as a knowledgeable peer.

Declarative Statements Uphold Unbalanced Academic Status Positions

In the subsequent exchange, Alison and Justin engaged in a back-and-forth about how to move forward with their proof that elements of a Cayley table are unique (see Ellis & Alzaga Elizondo, 2023).

Alison: Yeah it's different actions but I think for the sake of our proof we need to somehow say we're limited to you know (pause) [Statement]

Alison: just four, well in this case we don't have- however many symmetries there are. (pause) [Statement]

Alison: I might be articulating that wrong. (pause) [Statement]

Justin: I think the original route we're going down is right, where we have this, I think this is definitely the right way. [Statement]

Justin: I'm just trying to make sure that we have the proper way saying that proper, like-

Alison: Yeah, I agree, we have to find the way to set it up before we can just say. (pause) [Statement]

Justin: Well, (cross talk with Abigail) I just want to make sure there's no holes, I guess- [Statement]

Abigail: (cross talking) Q is identical to W then [Statement]

Alison: (responding to Justin) I understand that. [Statement]

Using declarative statements as discursive moves seemed to assert each speaker's own knowledge and authority over the work. For instance, Justin made a declarative statement evaluating Alison's prior contribution ("I think the original route we're going down is right"), positioning himself with the right to validate the group's work. Alison responded with a declarative statement "Yeah, I agree, we have to find the way to set it up..." which functioned as a positive evaluation of Justin's contribution. Rather than offer or invite a suggestion for how to accomplish what they agreed they needed to do to move the proof forward, Justin used another declarative statement, "I just want to make sure there's no holes" maintaining his right to validate their mathematical work. Instead of using questions to elicit intellectual contributions, as in the exchange between Alison and Lee, this interaction pattern functioned to uphold Justin's higher relative status he entered the interaction with.

Discussion

This report contributes a potential theory to empirically identify how status hierarchies form in small group interactions. We have argued that exploring processes by which status hierarchies form is necessary in proof contexts because such qualitatively-driven empirical analyses can potentially explain prior inequitable quantitative results, particularly regarding gender. While this theoretical approach seems fruitful, it has limitations. Additional data about students' experiences in group work is needed to obtain a more complete picture of how de/legitimizing status hierarchies attenuates/amplifies inequities in small group interactions (see Adams-Wiggins et al., 2020). Specifically, sociometric data about social relations in the classroom environment and interviews to allow students the opportunities to elaborate on their experiences would serve as appropriate data sources to confirm or disconfirm our interpretations from the status analysis. We hope this work sparks conversations around how status functions in small groups for the purpose of discussing and implementing possible instructional approaches that delegitimize status hierarchies in proof spaces.

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