Power Implicit in Discourses of Mathematical Rigor Within an Equity-Oriented Improvement Community

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"Rigor" is often used as a benchmark to determine whether mathematical work is sufficiently high-quality, and, thus, has significant bearing on students' course success and continuation in STEM majors. However, judgements about what constitute rigor are deeply subjective and may function as a vehicle for social bias. To interrogate possible connections between disciplinary standards and exclusionary gatekeeping, we analyze references to rigor by members of an "elite" mathematics department's equity-oriented change community. Our findings exhibit how participants' perceptions of rigor unveil a culture of power operating in undergraduate mathematics. We conclude with implications for research and practice.

Keywords: rigor, discourse, culture, power, equity

Introductory college mathematics courses, such as calculus, function as core pre-requisites for many university STEM majors and therefore impact STEM attrition rates (Weston et al., 2019). Given national disparities in tertiary STEM retention along axes of race, gender, and first generation status (e.g., Costello et al., 2023; Maloy et al., 2022; Park et al., 2020; Ortiz-Martínez et al, 2023; Suárez et al; 2021), advancing equity in the context of calculus curricula and instruction has become a central concern in undergraduate mathematics education. Mathematics departments and instructors often use "rigor" as a standard for the quality of their courses. Despite its role as a widely-used standard there is no agreed-upon definition of rigor; the term carries different meanings across individuals and mathematical contexts (Authors, under review). As an ambiguous standard that mediates inequitable STEM retention, it is possible that conceptualizations of rigor—and their implementations through instruction—embody unexamined disciplinary biases.

To further our collective understandings of how rigor and equity may interact in undergraduate mathematics instruction, we analyze an equity-oriented community of mathematics faculty and students at an elite institution, who adopted rigor as a focal issue to guide equity-intended change initiatives. Leveraging critical discourse analysis (Fairclough, 1989, 2013), we investigate implicit understandings of the term "rigor" and how those understandings get operationalized to maintain or disrupt hegemonically-focused practices in mathematics classrooms as a gateway to STEM degree attainment. Specifically, we guide this contributed report with the following research question: *How do discourses around rigor reveal a culture of power in undergraduate mathematics education?*

Conceptual Framework: Culture of Power

Delpit (1988) theorized that educational values are shaped by a culture of power (CoP), evidenced through five characteristics:

1. Issues of power are enacted in classrooms.
2. There are codes or rules for participating in power; that is, there is a culture of power.
3. The rules of the culture of power are a reflection of the rules of the culture of those who have power.
4. If you are not already a participant of the culture of power, being told explicitly the rules of that culture makes acquiring power easier.
5. Those with power are frequently least aware of—or least willing to acknowledge—its existence. Those with less power are often most aware of its existence (p. 282).

To elaborate on these characteristics, we leverage the original context of antiblackness in K-12 literacy education as an illustrative example. Delpit describes how issues of power are enacted in classrooms through the differential recognition of some forms of language as 'correct' while others are deemed incorrect or informal. Linguistic conventions deemed 'correct' are codes for participating in power. For example, students who speak and write 'correctly' generally have more access to careers that yield financial power and societal standing. These linguistic conventions align more closely with those commonly used in white households than in Black households, a reflection of cultural norms held by those with more societal power. Students, therefore, must be taught these linguistic codes of power when they do not acquire them through their households. However, many liberal/progressive white teachers oppose teaching these conventions directly in favor of approaches that encourage more freedom for students to use the language style that they prefer. Consequently, education systems may unjustly perceive Black children as requiring linguistic remediation upon entering formal education, which can have long-term ramifications for their access to power. In this way, teachers' desires to cultivate deep thinking and creativity can inadvertently perpetuate racial stratification through language instruction by centering children who have already assimilated to the CoP.

In the context of undergraduate mathematics education, we recognize that rigor plays an analogous role to language standards within K-12 literacy. Correctness is determined through rigor (however it may be interpreted by instructors/authorities), which can favor mathematical grammar over substantive reasoning. Rigor is capital; those who do mathematics with 'rigor' gain more access to success in their courses and STEM degrees. Here, we explore how rigor may function to uphold a CoP within undergraduate mathematics education.

Literature Review

Articles as early as 1920 argue for and also question the privileged role 'mathematical rigor' plays within mathematics education (e.g., Pierpont, 1928; Kitcher, 1981; Kleiner, 1991). These writings emphasize how conceptualizations of rigor, and thus the associated aims of enhancing such rigor, vary considerably. In particular, rigor is highly context- and position-specific; and thus mathematics students and faculty define general academic rigor differently (e.g., difficulty versus higher-order thinking; Cristobal et al., in press; Draeger et al., 2013; Draeger et al., 2015).

This ambiguity in what constitutes rigor raises questions about its potentially biased role in classroom practice and policy. Scholars have viewed rigor as completely separate from, or even in opposition to, care, equity, and inclusion in higher education (Marsellas, 2021; McNeill & Gresalfi, in press). Rigor can be operationalized through instruction to perpetuate existing inequities. Leyva et al. (2021) describe how instructors' standards for rigor can be experienced as part of a "weedout logic," through which students who are deemed "not cut out" for STEM are discouraged or prevented from continuing in mathematics coursework. One Latino student directly interpreted an instructor's remark as "t[a]k[ing] a shot at [his] self-esteem" through imposing "very rigorous" standards that activated racial stereotypes of mathematics ability. In

this way, standards of rigor may lend a false sense of legitimacy to the categorization of certain (groups of) students as mathematically incapable, akin to Delpit's (1988) observation of racial stratification justified by marking young Black students' language as incorrect.

Discussing the elitism of 'rigorous' mathematics within the engineering discipline, Riley (2017) notes that definitions of rigor are socially constituted; conceptualizations of rigor reflect existent social hierarchies and dominant presumptions about who can conduct 'rigorous' science. They assert that invoking rigor often functions to maintain exclusion through its assertion of white masculinized heterosexual power, drawing boundaries around what competent disciplinary practice and perspectives are, and academically punishing students to discount interdisciplinary or innovative scholarly work, including work which is oriented toward benefiting marginalized populations. They come to the conclusion below:

> "While many successful programs in mentoring and support for students of color and white females have been established over decades, these change efforts will be self-limiting as long as our standards of rigor work to reinforce gender, race, and class hierarchies in engineering, and further maintain invisibility of queer and disabled engineering students" (p. 261).

In response to this conclusion, Riley provides tenants upon which alternative conceptions of rigor might be built, one of which is facilitating abundance instead of the competition that common conceptions of rigor rely on. They highlight that this involves knowing that strengths can come from a variety of sources and working toward facilitating greater opportunity for broader engagement, as well as building up colleagues (and students) through "criticality in a caring process" (p. 262). Riley simultaneously acknowledges that coming up with an inclusive definition of rigor is an immensely daunting task, and straightforwardly advocates for "doing away with the concept altogether so we can welcome other ways of knowing" (p. 263).

However, in many institutional realities, rigor—as a word and as a concept—remains central to many conversations in undergraduate (mathematics) education. While departments work to enhance or maintain rigor in our undergraduate mathematics courses, it is necessary to think critically about how we define rigor, as well as what functions the invocation of rigor might perform. Towards this end, Gutiérrez (2013) argues that "making dominant discourses more apparent is a necessary step toward both recognizing how those discourses dis/advantage individuals and in challenging those discourses and their associated practices so as to put new ones into place" (p. 50). We respond to this call through a critical discourse analysis of rigor, and how an implicit CoP surrounding mathematical rigor may contribute to such dis/advantages.

Data and Method

This analysis comes from a larger study on Networked Improvement Communities (NICs) under the Achieving Critical Transformations in Undergraduate Mathematics Project (ACT UP Math). Through this project, education researchers with equity specializations partnered with three mathematics departments to initiate equity-intended changes, supported by equity-oriented professional development, quantitative and qualitative data, and a broader network of support across the three departments. We selected *Kappa University* as a focal institution for the present study in alignment with their NIC's focus on addressing rigor. Perhaps related to the NIC's identification of rigor as a change priority, Kappa is a highly selective institution where students and instructors alike expect difficult mathematics courses; Kappa students characterized the courses as "unnecessarily hard." As such, the Kappa NIC context serves as a fertile ground for reckoning with tensions between the perceived value, inherent ambiguity, and operationalized impacts of rigor.

The Kappa NIC was composed of four faculty affiliated with the introductory mathematics program, two graduate students who had taught in the introductory mathematics program, and two undergraduates who had taken classes within the introductory mathematics program. Research participants opted into the NIC with interests of contributing to equity-oriented change and were all equally paid by ACT UP Math. Faculty (Anna, Senna) were invited by the two NIC faculty co-leaders (Tiersa, Skylar), and the graduate (Parker, Kiara) and undergraduate students (Ricardo, Timothy) were purposefully selected out of an application pool. The NIC predominantly identified as white women, but included one woman of color and two men.

Data consists of journals and structured interviews from the eight NIC members, collected from Spring 2023 to Spring 2025. Journals were collected intermittently and prompted participants to reflect on their experience with the NIC, with some journal prompts asking specifically about participants' understandings of rigor and their progress towards addressing rigor in their undergraduate program. Interviews were conducted once per semester, typically within the latter half of the semester.

Data Analysis

We selected a subset of data for analysis by locating instances of the word "rigor," taken together with relevant context. We leveraged critical discourse analysis—a method that examines how ideologies related to societal power relations shape discourse, both implicitly and explicitly (Fairclough, 1989, 2013). Our multi-stage analysis proceeded as follows, methodologically aligned with reflexive thematic analysis, which generally includes six phases: familiarizing yourself with the dataset; coding; generating initial themes; developing and reviewing the themes; refining defining and naming the themes; and writing up the analysis (Braun et al., 2023). First, we read through all responses to the journal prompt "What does mathematics rigor mean to you?" as a basis for our preliminary codebook. The second stage consisted of developing our codebook using the subset of data which mentioned "rigor" and its surrounding context. As the codebook developed, each excerpt was coded by at least two authors, wherein different interpretations of an excerpt were reconciled within partner-to-partner or full group discussions. Multiple excerpts were coded with multiple codes. As we organized these codes into themes, we recognized the underlying CoP and organized codes according to the five characteristics of CoP to address our research question: *How do discourses around rigor reveal a culture of power in undergraduate mathematics education?*

Findings

To structure our investigation of rigor as imbued with implicit power in mathematics, we organize our findings according to Delpit's (1988) five characteristics, with brief empirical illustrations provided for each.

Issues of Power are Enacted in Classrooms

NIC members learned from student feedback on a survey and through a focus group that many students experienced Kappa mathematics courses as "unnecessarily hard." The NIC members attributed these perceptions of the course as unnecessarily hard to how rigor was enacted in classes, and led to the NIC's decision to explore rigor as their shared goal: "This idea of being unnecessarily hard… really informed that decision to interrogate rigor" (Tiersa). Given that rigor was a widely-held value in the department, including among members of the NIC, participants grappled with emphasizing rigor through their teaching. Tiersa commented that, "Instructors are feeling like 'rigor is the key component of my class', and students are feeling

like 'rigor is the thing in class that is destroying me,'" while recognizing that for students, the emphasis on rigor "can feel like gatekeeping." While participants recognized the power exerted by instructors in some cases, at other times power was implicit in their own values around rigor. For example, Skylar shared, "My dream would be to change the narrative of Kappa math, so that it is no longer perceived as 'unnecessarily hard.'" In desiring to change how students *perceive* rigor rather than the ways rigor is *enacted* in classes, Skylar left intact the assumption that rigor is inherently valuable and students must adjust themselves accordingly.

There are Codes or Rules for Participating in Power; That is, There is a Culture of Power

When discussing rigor, participants described many codes and rules associated with rigor, which were especially pronounced in relation to proof and notation. However, they also recognized these codes and rules were largely unrelated to students' academic development. For example, Parker noted,

> There are times where [rigor] is important when you're, like, writing up a proof because… you're publishing it. And someone on the internet is going to read it… [and] you won't necessarily be given the option to explain yourself later, and you want to be rigorous with how you write it up to do your very best at being understood correctly. But that's not necessarily why our students are learning math.

Parker frames adhering to written conventions related to rigor as important for mathematicians who may be publishing their work, but less important for students. In this way, codes and rules surrounding rigor can be seen as cultural values that arise from professional imperatives among mathematicians rather than conventions that are necessary to support students' learning. Supporting this view, Kiara suggested that adhering to rules and codes surrounding rigor may be antagonistic to goals of preparing students to apply their mathematical understanding to their major discipline when teaching Calculus II:

> Mathematical rigor at a course level sometimes loses sight of the point… to equip students with tools that they will hopefully use in whatever discipline they want to… it's not always most appropriate for us to go through proofs very carefully… On some level it does feel useful for students to see… what a proof looks like… to carefully check details starting from a definition and moving towards a proposition or a statement. And yet at the same time, maybe that's not the key skill that we want to be moving through.

Kiara's description references specific codes and rules associated with establishing rigor (e.g., "starting from a definition"). However, they perceive these codes as in tension with the goals of mathematics learning. This reinforces a view that the codes and rules of rigor are the product of cultural values within the mathematics discipline, functioning as a CoP.

The Rules of the CoP Reflect the Rules of the Culture of Those Who Have Power

Participants framed the adherence to rigor conventions as culturally rather than pedagogically motivated. Their discussions of rigor suggested, both implicitly and explicitly, that these cultural mathematical values aligned with racial and socioeconomic power differentials. For example, when discussing which marginalized group to focus on to guide instructional improvements, Skyler shared the NIC considered "students of color and students who come from… less rigorous high schools," because this population experienced "culture shock" when moving from schools that "didn't even offer calculus" to being in "classrooms with people who took linear algebra already." Given the tendency for 'rigor' in secondary schools to align with socioeconomic status (Palardy, 2013), Skylar's description draws an implicit correspondence between rigor and race and class inequality, suggesting those who value and are familiar with rigor constitute a racially

and financially privileged group.

Racial inequities were named infrequently but explicitly when participants discussed qualities of rigor. For example, pertaining to notation, participants discussed, without naming, the "worship of the written word"—a quality of white supremacy culture (Okun, n.d.) which can dismiss the perspectives of marginalized people due to syntax. NIC members questioned the precise grammar of rigor, claiming that instructors "making sure that they're getting the exact correct notation every time is not necessarily in their [students'] best interest" (Parker).

Being Told Explicitly the Rules of that Culture Makes Acquiring Power Easier

In line with Delpit's (1988) work, participants advocated for explicit teaching about rigor when rigor was deemed necessary. For example, when discussing notation, Tiersa considered changing the way she evaluated student work to validate "different dialect[s]" and to be explicit about expectations for notation when she could not.

> I don't want to be picky about notation, and I wanna make sure that I'm trying to understand what my student is saying, even if they're saying it in a way that's different from how I would say it, when I'm evaluating their work. And if I am gonna be picky about something, I better be really clear about whatever it is I'm being picky about.

Beyond the specific example of notation, participants challenged the rendering of rigor as an unquestioned, implicit expectation in calculus classrooms. As an example, Parker shared,

> I… tell my students… when it's okay to not be as rigorous… There's so much that we don't tell students, that we just say… "You have to learn this because it's important." …[I'm] taking that away a little bit… [at] times I'm like, "This is correct. I would like you to use this [notation], but I also understand if you don't"... showing a little bit more of that flexibility with the ultimate goal of them learning math… and put it together for themselves, instead of just doing what they've been told, because they were told "Do it."

Parker describes being explicit about when and why rigor was required, distinguishing between students' performance of rigor and their mathematical comprehension. These instructional aims recognize that explicit instruction helps students acquire rigor as a form of power in mathematics, while also decentering rigor as the "right way" to do mathematics. It is possible such explicit forms of instruction mitigate the racial and socioeconomic stratifications that arise through students' differential pre-college exposure to rigor.

Those with Power are Frequently Least Aware of Its Existence

Although participants occasionally acknowledged links between rigor and social power tied to race and class, more frequently they revealed a lack of certainty about rigor's relationship to broader inequities. As an example, Anna shares how "interrogating rigor [in the NIC]… was student driven" and that "if it were just [her] and [her] own silo, [she] would say 'I'm not looking at that [student work] because it's not rigorous enough'", which we interpret as maintaining rigor as a benchmark for evaluating hypothetical student work. She does recognize that she does need to "keep figuring out how to maintain [rigor] in the class while still keeping things accessible or making things more accessible and inclusive," implicitly contrasting rigor with accessible or inclusive classes. The NIC's tensions with recognizing potentially exclusionary aspects of rigor was also notable when Skylar brought a discussion topic to the NIC about possible connections between white supremacy and rigor, operationalized through rigid notation expectations.. Skyler noted that when they raised possible connections to white supremacy, the NIC "veer[ed] away from criticality," consistent with an avoidance of recognizing racial power—a common move among those who benefit from it (Bonilla-Silva,

2006).

Participants often expressed a lack of clarity and sometimes concern about how rigor and the team's explicit broader goals of advancing equity were related, particularly because they engaged a critical perspective that explicitly connected equity to identity. For example, commenting on students' common perception of rigor as "unnecessarily hard," Tiersa questioned, "what's the particular population or group that feels like things are unnecessarily hard?" After reflecting on how rigor relates to issues of power mediated through mathematical notation, they also shared,

> I don't know where the diversity, equity, and inclusion are in what I've just said…. I'm coming back to this 'for all' kind of language… I guess I'm not sure how that [notation] interacts with this idea of helping include people who haven't been well included.

Similarly, Skylar reflected "we really haven't talked much about student identity at all in this group, not even the sort of students with less rigorous high school experiences." Hence, although participants were attentive to power dynamics in the instructor-student relationship, they demonstrated a limited awareness of how rigor was tied to power in broader society. Participants' separating rigor from equity reveals their lack of awareness that rigor itself is part of the CoP they inhabit—and from which they benefit.

Discussion and Implications

Riley (2017) highlights the parallelism between the dual meanings of rigor—as both academic credibility and hardship—and of discipline—as both an academic field and corrective control. The CoP revealed through our findings demonstrates the confluence of these multiple meanings of disciplinary rigor, linking widely-held and seemingly-neutral mathematical values with the exclusionary impact of introductory undergraduate mathematics courses. While some work has importantly identified aspects of classroom practice that may contribute to racialized and gendered exclusion from STEM (e.g., Leyva et al., 2021), our analysis contributes to an emerging body of work that interrogates mathematical values as a root from which exclusionary teaching practices emerge (McNeill & Gresalfi, in press).

Delpit (1988) concludes by naming a number of ways to move beyond the limiting and exclusionary confines of the CoP within K-12 literacy education, including to give students opportunities to be authentic and creative in their writing while also explicitly teaching the cultural convention of writing. This resonates strongly with many current debates around modern pedagogical approaches within undergraduate mathematics and thus has implications for both our practice and future research. Mathematics educators seeking to improve student experiences by cultivating deep thinking and creativity within mathematics may see this as at odds with directly teaching mathematical conventions of rigor, similarly centering students who have already assimilated to the CoP within undergraduate mathematics. However, through the lens of CoP we recognize rigor as cultural capital, and thus see a need to make its value and form explicit, especially for students who have not yet assimilated to the CoP. We call for future research to take up and explore the role of rigor across undergraduate mathematics education to further theorize how instruction can move towards equitable mathematics learning within a CoP.

Acknowledgments

Authors 3-7 are listed reverse alphabetically; we all contributed substantially to this research with authors 1 and 2 taking the writing and conceptual development lead. We are grateful to the ACT UP Math project, funded by the National Science Foundation (EES #2201486) until funding was terminated by DOGE. All findings are those of the authors.

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