Observing whiteness in introductory physics: A case study

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Within whiteness, the organization of social life is in terms of a center and margins that are based on dominance, control, and a transcendent figure that is consistently and structurally ascribed value over and above other figures. In this paper, we synthesize literature from Critical Whiteness Studies and Critical Race Theory to articulate analytic markers for whiteness, and use the markers to identify and analyze whiteness as it shows up in an introductory physics classroom interaction. We name mechanisms that facilitate the reproduction of whiteness in this local context, including a particular representation of energy, physics values, whiteboards, gendered social norms, and the structure of schooling. In naming whiteness and offering a set of analytic markers, our aim is to provide instructors and researchers with a tool for identifying whiteness in their own contexts. Alongside our discussion, which imagines new possibilities for physics teaching and learning, we hope our work contributes to Critical Whiteness Studies' goal of dismantling whiteness.

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I. INTRODUCTION

Critical Race Theory names that racism and white supremacy are endemic to all aspects of U.S. society, from employment to schooling to the law [1–7]. We see the outcomes of this in, for example, differential incarceration rates, rates of infection and death in the era of COVID, and police brutality. We also see the outcomes of this in physics. For example, the American Physical Society [8] reports that whereas almost 16% of the U.S. population aged 20–24 years is Black, only 3% of bachelor's degrees in physics and 1.8% of doctorate degrees are awarded to Black students. This is in contrast to about 73% of the U.S. population aged 20–24 being white,[1] and 72% and 75%, respectively, of bachelor's and doctorate degrees being awarded to white students. Critical Race Theory would cite this as evidence that white supremacy, or the "systemic maintenance of the dominant position that produces [w]hite privilege" [5], is shaping degree granting (and all of the processes and practices therein) in physics.

For physics educators and physics education researchers, this outcome and others like it motivate questions about what is happening, at the level of classrooms and universities, that constructs and maintains whiteness. Recent work by Physicists and Physics Students of Color point to a number of mechanisms, from being repeatedly asked why they are in physics courses or told to change majors [11–14]; to suffering unequal consequences for engaging in physics norms of competitive argumentation [15]; to being disparaged by colleagues, not looked in the eye, and excluded from study groups [9,12,16]; to needing to fragment themselves to participate in local physics culture [13,17,18]; to experiencing tone policing when advocating for social change in their departments [15,19,20]. This paper seeks to amplify these voices and add to this growing body of literature. Specifically, we focus on the reproduction of whiteness in an introductory physics classroom, illustrating what this process looks like and identifying some of the tools, practices, and disciplinary values that reify and reconstitute it. Drawing on case study analytic techniques [21,22] and Critical Whiteness Studies [23–34], our purpose is to make whiteness visible, both for instructors who may wish to identify whiteness in real-time interaction and for researchers who may wish to study it.

The paper first presents our theoretical framework, including analytic markers that we use to make whiteness visible in the paper's focal episode. Before we present our

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[1]In this paper, in most cases we choose not to capitalize white and do choose to capitalize Black, Hispanic, and Students or People of Color. (The exception is when referring to Critical Whiteness Studies, which is a formal term that is capitalized in the literature.) This choice is informed by critical scholarship and activism, such as that by Dumas and the PoC in PER group [9,10]. For example, Dumas writes that Black is a "self-determined name of a racialized social group that shares a specific set of histories, cultural processes, and imagined and performed kinships." White, on the other hand, is a socially constructed category that was created for the purposes of dominance and exclusion; it "does not describe a group with a sense of common experiences or kinship outside of acts of colonization or terror."

analysis, we detail our methods (Sec. III) and the instructional context for the episode we analyze (Sec. IV). Our analysis in Sec. V includes not only what whiteness looks like in the focal interaction but also what we see as contributing to the local reproduction of whiteness. In our discussion (Sec. VI), we reflect on our findings and offer one set of imaginings of what else may be possible.

II. THEORETICAL FRAMEWORK: CRITICAL WHITENESS STUDIES

One central goal of Critical Whiteness Studies [23–34] is to make whiteness visible—to "unmask the racial character of many of these [normative] practices and beliefs; to make visible what remains invisible" [25]. A central premise of Critical Whiteness Studies (CWS) is that the taken-for-granted and invisible nature of whiteness is a primary means through which white dominance goes unchallenged [23,24,29,33], such that making whiteness visible is one way to disrupt white dominance.

CWS argues that whiteness' hidden-ness is grounded in the dynamics of dominant group status [23,24,29,33], since the sociopolitically and (historically) numerically dominant group have been able to appropriate the social and cultural "mainstream" and make white understandings and practices normative. The invisibility of whiteness then *maintains* dominance: invisibility helps "foster the illusion that those who succeed do so because of their superior intelligence, their hard work, or their determination, rather than, at least in part, their privilege" [29].

In CWS, whiteness is socially constructed for the purposes of dominance and exclusion; it is not a biological reality [23,24,27,29,33]. Doane [23] writes that

> *"In the context of race, 'whiteness' must be understood as a position in a specific set of social relationships—a 'racialized social system'…—and as a historically contingent social identity…[T]he hardening of group boundaries and the racialization of whiteness are modern phenomena linked to European conquest and colonialism…and the spread of global capitalism. The construction of white identity develops through the creation of 'otherness.'"*

Thus, CWS maintains that whiteness is a social organization linked to dominance and control [23,35,36]. Whiteness as social organization produces a center and margins; those who are dominant hold privilege and power and control access to the center and its attendant privileges. In this framework, a critique of white racial supremacy revolves less around unearned advantages, or the *state* of being dominant, and more around direct processes that secure domination and the privileges associated with it. Because whiteness is often invisible and normative, evidence for whiteness is often named in terms of *outcomes*—e.g., differential outcomes based on race, or lived experiences of oppression and marginalization.

One critique of CWS is that in focusing on whiteness, CWS "reasserts and reinstates it" while also attempting to "deconstruct" it. Further, CWS can sometimes ascribe an omnipresent power to whiteness, treating whiteness and white people as "the key agents of historical change" and assuming that "the problems of racism can be solved by white people changing their minds," ignoring the structural and systemic layers of racism [24].

Our analysis of the focal episode in this paper draws on Critical Race Theory and CWS to make whiteness visible and to name some of the practices and narratives that reify and reconstitute it in one physics classroom space. For the purposes of our analysis, we define whiteness in the following way: Within whiteness, organization of social life is in terms of a center and margins that are based on dominance, control, and a transcendent figure that is consistently (and structurally) ascribed value over and above other figures. This is in contrast to an organization of social life that organizes around plurality, mutuality, and community care [37,38]. Notably, this definition does not require actors be white in order to participate in whiteness, even if the benefits of participating may be conferred disproportionately to white or white-passing people. Proximity to whiteness and/or passing as white is "a feature of race subordination in all societies structured on white supremacy" [39]; the "color line," as DuBois puts it, is a spatial reality that separates, divides, and shapes the experiences of individuals based on their proximity to it [40].

Drawing on the literature, we name the following as analytic markers of whiteness as social organization:

- *Organization of social life that resembles a center with margins*, where what is at the center is ascribed value over and above other figures [35,36,39,41–44]. Whiteness as social organization requires a less-valued "other" to define itself—i.e., the value that is ascribed to the center is always in relation to it being not the other (or not the margins). Bang writes, "… claims of epistemic authority [e.g., that *xyz* is right or correct] created a dialogic inevitability—the construction of epistemic inferiority—and gave rise to epistemic racism and sexism (i.e., a stance that 'privileges as superior Western male knowledges and treats as inferior knowledges that are women centered and non-Western'") [37,45]. Building from this, in whiteness as social organization, features of the center can be traced to ideals that fueled colonization (or are Eurocentric by default), since whiteness emerged out of European conquest and colonialism [2,37,41,42,46,47]. System-wide, there will be pervasive messaging around the value of the ideal at the center. For example, DiAngelo[2] [48] writes,

[2]DiAngelo, a white woman, has been critiqued by Activists of Color for profiting from her work on whiteness.

"Living in a white dominant context, we receive constant messages that we are better and more important than people of color. For example: our centrality in history textbooks, historical representations and perspectives; our centrality in media and advertising; our teachers, role-models, heroes and heroines; everyday discourse on "good" neighborhoods and schools and who is in them; popular TV shows centered around friendship circles that are all white; religious iconography that depicts God, Adam and Eve, and other key figures as white. While one may explicitly reject the notion that one is inherently better than another, one cannot avoid internalizing the message of white superiority, as it is ubiquitous in mainstream culture."

- *Meritocratic and other frames of race evasiveness*[3] (abstract liberalism, naturalization, cultural racism, minimization of racism) used to explain the creation and/or maintenance of the center [3,7,35]. Within whiteness as social organization, people may have difficulty naming what is in the center, and/or difficulty understanding what is in the center as anything other than meritocratic outcomes.
- *Constraints on people's agency* to engage in mutuality and community care [50], even when these may be centrally held values. This may be exacerbated for people who are living at the intersection of multiple sites of oppression [51,52].
- *Mechanisms of control* that enforce the center and discipline those who challenge or seek to disrupt this social organization [2,42,51,53]. Individual people may escape negative consequences by behaving "correctly," or based on their proximity to whiteness and/or other forms of dominance. The *threat* of consequences, though, is ever-present and often sufficient to shape behavior.
- *Differential outcomes* that map onto racialized, gendered, and/or classed identities [42,51]. Tied to the previous marker, people may rely on the frames of race-evasive ideology, including cultural racism, or the white racial frame [46] to construct or reify cultural narratives that justify differential outcomes. For example, drawing on the white racial frame, someone may argue that the employment rate for Black Americans is lower than white Americans because Black people are "unintelligent" and "lazy," rather than seeing differential employment rates as a marker of whiteness. In whiteness as social organization, we would also see fragility on the part of the centered folks at the suggestion that outcomes are racialized, gendered, etc., rather than meritorious or "natural."

[3]We use the language of race evasiveness, rather than color blindness, because color blindness, as a term, "conflates lack of eyesight with lack of knowing" and is thus "inherent [ly] ableis[t]" [49].

In this paper, we use these markers in our analysis to point to whiteness as social organization.

Within the literature on whiteness, there is not a single, consistent "kind of thing" that whiteness is: whiteness has been named as a racial frame (which includes bias), an ideology, a social organization, and an identity [5,35,36,46,54]. Babb captures the difficulty of pinning whiteness down, one mechanism through which whiteness maintains power and invisibility:

"Part of the difficulty in characterizing whiteness lies with its having no genuine content other than a culturally manufactured one, developed unevenly over a period of time, influenced by and responding to a variety of historical events and social conditions: among them, the need to create a historical past, the need to create a national identity, and the need to minimize class warfare. As whiteness evolved in response to these demands, it did so in no linear or orderly fashion, had no single abiding vision that created it, had no single source from which it sprang. It unfolded ad hoc, as a mishmash of elements attuned to an ever-changing American culture. In different periods, a variety of symbols, laws, and institutions have been mobilized to sustain the concept of whiteness, and over time, repeated representations have cemented its identity."

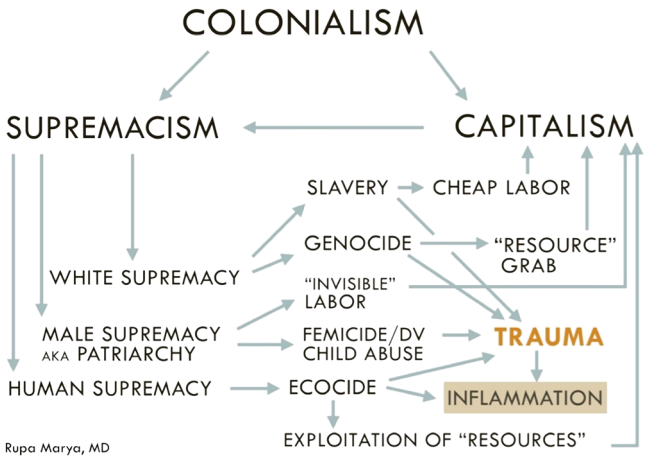

FIG. 1. Flowchart from Marya, "Health and Justice—The Path of Liberation Through Medicine," published as a Medium article on 06/12/2020, accessed 06/26/2020 [55]. Reproduced with permission from the author. Many thanks to the Decolonizing Education Conference for making us aware of Dr. Marya's work. Image description: A flowchart illustrating how multiple forms of oppression are related, and how these lead to multiple forms of harm. At the top is colonialism, which leads to capitalism and supremacism, which are themselves connected. These flow into white supremacy, patriarchy, and human supremacy, which fuel things like slavery, ecocide, and genocide, which all connect to trauma and then inflammation. Multiple forms of harm are connected back up to capitalism.

Though our analytic markers draw on literature that spans conceptualizations of whiteness as a frame, ideology, social organization, and identity, our focus in this analysis is on whiteness as social organization. *This choice is not meant to communicate that whiteness as social organization is best for describing whiteness;* whiteness is pervasive, insidious, and complex, and it manifests in all of the ways above. We chose whiteness as social organization because we want to show how physics classroom spaces can mirror the *structure* of whiteness, in moments where race is not an overt topic of conversation and/or events may seem neutral. Drawing on CWS, our belief is that spaces are racialized *insofar as they mirror or take up this social organization*.

Figure 1 illustrates that systems of marginalization and oppression often share mechanisms and characteristics, and all can be conceptualized as rooted in colonialism, where "colonizers aim to establish dominion over the desired homelands" or labor market [45]. As in Fig. 1, the specific manifestations of these systems and mechanisms of oppression may be different, and often multiple systems of oppression are at work at once. We are foregrounding whiteness in our analysis because of our positionalities (see Sec. III) and the theoretical framework we chose (CWS), though we do briefly discuss how we see patriarchy working with whiteness to produce the dynamics of the episode we analyze.

III. RESEARCH METHODS

In the tradition of Critical Whiteness Studies, our goal in this study has been to "make whiteness visible," and particularly to make clearer the "ordinariness" of whiteness in introductory physics classrooms. This purpose is well served by case study analysis, where analysts select *cases of theories in context*, for the purposes of illustrating, refining, or building theory. Case studies can demonstrate what is possible, clarify participants' points of view, reveal or challenge implicit assumptions, identify mechanisms that produce social phenomena, and make the ordinary "extraordinary" [21,56–58].

In this paper, we analyze a *case of* whiteness as social organization from an introductory physics course at a large public institution in the Western United States. We use the analytic markers from Sec. II to illustrate how whiteness shows up in this context, and we identify and discuss a number of mechanisms of control that co-produce whiteness in the six-minute episode of classroom interaction. We draw on tools of interaction analysis [59], including discourse, gesture, and gaze analysis, to unpack how whiteness is being constituted locally or interactionally. Our hope is that illustrating whiteness as social organization can contribute to readers' awareness of and vision for disrupting and transforming this social organization in their own contexts [56,60] and support other researchers who want to do similar analyses.

Though we do not use situated learning theory (SLT) [61,62] extensively in our analysis—i.e., this is not an analysis of learning or identity as much as it is a study of cultural and ideological reproduction—we are influenced by SLT. That is, the social organization of the classroom is being thought of in terms consistent with SLT—e.g., central, marginalized, reified.

Importantly, CWS and Critical Race Theory argue that whiteness is *actively* maintained, at both interpersonal and institutional levels. But ours is *not* an analysis of individuals as racist; in fact, the individuals-as-racist story fuels whiteness by treating each incidence of racialized harm as an exception, recusing white people from addressing structural harm, and by focusing on intent rather than impact [3,42]. Our argument is fundamentally about whiteness as social organization and its pernicious normativity—how *whiteness* is acting, how whiteness constrains actors' agency, and how whiteness makes certain behaviors normal and/or sensible [63]. At the same time, we recognize that whiteness is reproduced interactionally, and that people participate in maintaining (and disrupting) whiteness [64]. We do our best to use language that neither reinforces the individuals-as-racists narrative nor shames actors for participating in sensible behavior within whiteness, while also acknowledging their agency.

Authors' positionalities.—Robertson is a chronically ill and disabled, physics-Ph.D.-holding, thin wealthy white woman. Her analysis and writing were shaped by these identities, including her "insider" status in physics: because of her socialization in the discipline, she is able to name and make sense of physics values, representations, and practices.

For most of Robertson's life, whiteness (including whiteness as social organization) has been invisible to her; this invisibility is rooted in part in the hegemony of whiteness and in Robertson's position of power within white-dominant culture [36,51]. Her efforts to "make whiteness visible" in the writing of this paper, then, reflect her position as a learner and as a white person; in writing this paper, she is sharing her in-progress learning, as someone who is waking up to the world as it is, with gratitude for the support of Friends, Scholars, and Activists of Color. Her position as a learner about whiteness has been *deeply informed* by her own marginalization and oppression as a chronically ill person. Because she was diagnosed with an autoimmune disease at the very young age of 2, she has no memories of the world that are not painfully marked by ableism. Though ableism and white supremacy are different, systems of oppression overlap and share mechanisms of control and dominance (Fig. 1); ableism and racism are both "normalizing processes that are interconnected and collusive" [65] (e.g., the discourses used to marginalize People of Color often rely on ableist narrations). In reading work by Scholars and Activists of Color, Robertson has felt resonances that have helped her to name and identify ableist harm and oppression in her own life, at both institutional and interpersonal levels. In turn, she

understands racialized harm and oppression from her (chronically ill) standpoint. Further, she stands with Freire [66], Lorde [67], and others in asserting that whiteness and white supremacy harm us all (as does ableism), and that our liberation is bound up in one another's. Robertson sees this paper as one piece of her effort to join the collective struggle for liberation from white supremacy.

Hairston is an African American male and lifelong learner, researcher, and educator of equity-inclusive frameworks. Educationally, Hairston was shaped by his diverse urban upbringing in a religious community. Experientially, he was greatly influenced by his work in community development in the global south. Hairston identifies with the larger historical narrative of pre-enslavement and precolonial African rootedness. For this project Hairston brings forward equity in education that is not centered in white normativity.

As one impacted by white identity in education both personally and professionally, Hairston relates to those systems that decentered his way of knowing and being. Education was an external performance that required translation into less harmful and traumatizing processes. Such processes countered the identity narratives pervasive in public education, especially during the days of busing in the United States. The double consciousness first alluded to by African American intellectual and statesman DuBois in the 1903 classic, *The Souls of Black Folk* [40], rightly codifies Hairston's lived and learned reality. DuBois describes the twoness as a sociocultural construct that is unreconciled and lacking resolve. Hairston uses such awareness in his equity research and attempts to provide such a worldview to the reader of this paper.

Pragmatics.—The episode in the paper takes place in a PER-informed introductory physics course at a large public university in the Western United States. As part of a larger project, a data collection partner at this institution video recorded four consecutive days of instruction and shared these video recordings with the project team; the instructor and recorded students consented to participate in our study. We then viewed the video multiple times to identify instances of centering and marginalization. Hairston originally selected and transcribed the analytic episode because it evidenced a variety of interactions where power and identity appeared to be interacting with or a part of the sensemaking process.

Robertson then conducted stimulated recall interviews [68] with two student participants from the focal group, one of whom was not present for the day the focal episode was recorded. Hairston did the same with the instructor of the course. In stimulated recall interviews, the interviewer showed participants short video episodes from their course and asked them to reflect on what was happening there and whether it was typical or atypical; sometimes there were targeted questions for specific episodes, such as, "Do you know what this participant meant when they said _____?," or, "I noticed that the instructor asks for evidence in this video. What kinds of things count as evidence in your class?" If there was time at the end of the interviews, the interviewer would ask more general questions about the course, such as, "What is the most important thing for people to learn in your physics course?" Stimulated recall interviews lasted approximately one hour and were done over Zoom.

Hairston and Robertson then collaboratively discussed the episode in meetings and co-constructed the message of this paper. Robertson worked on a detailed analysis and wrote, in consultation with Hairston, drawing on the theoretical framework articulated above. The instructor was given the opportunity to read the manuscript prior to submission and affirmed the interpretations here [69,70].

IV. EPISODE CONTEXT AND SUMMARY

Participants.—The focal episode in this paper features three students, pseudonymed Drake, Paris, and Gail, and their course instructor, pseudonymed Iris. In a stimulated recall interview, Paris refers to herself as a "Hispanic woman," and to Drake and Gail as "he" and "she," respectively. Gail presents as white, and Drake as middle Eastern.[4] Iris self-identifies as biracial and culturally white and uses she, her, hers pronouns. The participants' race and gender do not feature prominently in our analysis; our analysis focuses on whiteness as a social organization, with the aim of illustrating how "everyday" interactions in physics classrooms reflect and reify whiteness. Naming Gail and Drake's racial and/or ethnic identities for them, as we have, is fraught. However, because this classroom interaction takes place in the context of U.S. higher education, which is far from gender or race neutral [3,51], we can assume that the participants' race and gender *do* matter; they matter for the discursive positions available to them [50] and they matter in the sociohistorical context in which the interaction is playing out (and thus the meanings that participants may make of it). In addition, it is not only the participants' self-identified race, ethnicity, and gender that matter; it is also what others perceive their identities to be that matter [73]. We name what we observe and were told for this reason; it feels like important context.

Instructional context.—In the episode, Paris, Drake, and Gail work together as a small group in an introductory physics course at a large public institution in the Western U.S. The course draws extensively on physics-education-research-based methods, and course meetings often alternate between small- and whole-group discussion, with students collaboratively constructing answers to questions

[4]Middle Eastern is considered white according to U.S. federally mandated race categories [71], but middle Eastern people in the U.S. are subjected to and oppressed by white supremacy and Islamophobia [72].

in their groups and then sharing out to the whole class. Whiteboards feature prominently in the course; what is represented on the group's whiteboard is often what gets oriented to in the large-group share-out.

In this episode, Paris, Drake, and Gail have been tasked with constructing an answer to a series of questions about heat capacity. In particular, they have been asked to construct an energy interaction diagram (see Fig. 2) for measuring the heat capacity of a big bucket of water. They are then asked to use their energy interaction diagram and the definition of heat capacity to develop an algebraic relationship relating the change in thermal energy to the change in temperature and the heat capacity.

Energy interaction diagrams.—The energy interaction diagram (EID) is "a representation for energy dynamics in a physical system that highlights *energy conservation* and guides users to *derive a mathematical model* for energy changes in a system during a process of interest" [74]. EIDs foreground a model in which energy is a "substance-like quantity that can be contained in various *stores*" that are "distinguished by their respective observable manifestations…and transferred from one store to another within a particular physical system" [74]. Significant features of an EID include that the relevant physical process is indicated at the top of the diagram; the relevant time interval and initial and final conditions are indicated by a line with labels; the system is labeled within an open (dashed) or closed (solid) oval boundary, with any inputs or outputs of energy also labeled with an arrow; the stores that are experiencing a change are each included within the boundary in separate circles, with indicators and initial and final states; and any relevant quantitative modeling is featured at the bottom.

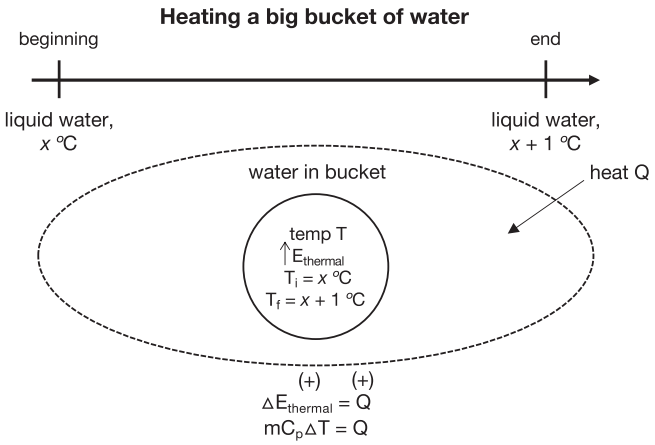

FIG. 2. Energy-interaction diagram for heating a big bucket of water. Image description: At the top of the diagram is a horizontal arrow, marked "beginning" on the left and "end" on the right. Under "beginning" is the caption "liquid water, x degrees C," and under "end" is "liquid water, $x + 1$ degrees C." Underneath the arrow is a set of concentric circles, the outer one dashed with the heading "water in bucket," and the inner one solid, with "temp T" in the middle, followed by an upward arrow labeled "E_{thermal}", followed by "$T_i = x$ degrees C," and finally, "$T_f = x + 1$ degrees C." The diagram indicates with an arrow that heat is entering the outer concentric circle. At the very bottom of the diagram are the situation-specific equations for the First Law of Thermodynamics and heat capacity.

For example, Fig. 2 is a correct EID for measuring the heat capacity of a big bucket of water. At the top of the diagram is the phenomenon of interest: heating a big bucket of water. The system is open (indicated by a dashed line), since heating is happening (and thus energy is being transferred into the system). There is only one "object" in the system, the water in the bucket. Because we are seeking to measure the heat capacity of the water, which is the amount of energy it takes to change the water's temperature by one degree Celsius, the time period of interest (represented by the solid line at the top of the diagram) is however long it takes to change the water's temperature by one degree. During that time, the only energy store that experiences a change in amount is thermal energy, indicated by temperature T. The (quantitative) amount of that change in energy is given by the equations at the bottom of the EID.

Importantly, EIDs discipline the modeling of an energy scenario, requiring users to coordinate across multiple considerations [75]. For example, the time interval determines which energy stores are changing, so the selection of the time interval needs to happen first. Likewise, the energy stores that are changing tell us what should go in the quantitative part of the diagram, and whether the system is open or closed tells us if the changes in energy should sum to zero (closed system, conservation of energy) or not. The structure and layout of the EID supports this ordering of activity and also communicates meaning—e.g., the "energy 'bubbles'," representing energy stores, are located "*inside* the oval system boundary," suggesting that "energy stores reside inside the physical system" [75].

Focal episode.—The six-and-a-half minute episode we analyze begins immediately after Iris (pseudonym), the course instructor, assigns problems to each group. Following this, Drake stands up, grabs a whiteboard marker, and begins drawing an EID (Fig. 3). He writes "system water" and draws an arrow to the right, like the one at the top of Fig. 2. Paris comes to stand at his side, with her gaze on the EID, and Gail joins her to the right (Fig. 4).

The first utterance comes from Drake; he says, "(inaudible) process is heating," as he turns back to his notebook, and Paris affirms this, saying, "Yes." He then writes "heating" on the whiteboard over the line he has drawn (Fig. 4). Gail, looking at a previous question in her lab book, laughs and comments that she "like[s] how it says European size, because we [in the U.S.] have such large portion sizes," initiating a light-hearted dialogue between the group and Iris about the person who wrote the lab book. Gail then clarifies which problem they are working on, asking, "We are doing two?," to which Drake answers, "Three and four." All three

FIG. 3. Drake stands up immediately after Iris assigns problems to his group. Image description: Drake (pseudonym) faces a whiteboard, standing, and is reaching for the marker. Paris is seated at the table, facing away from Drake. Gail is standing opposite Paris, standing up.

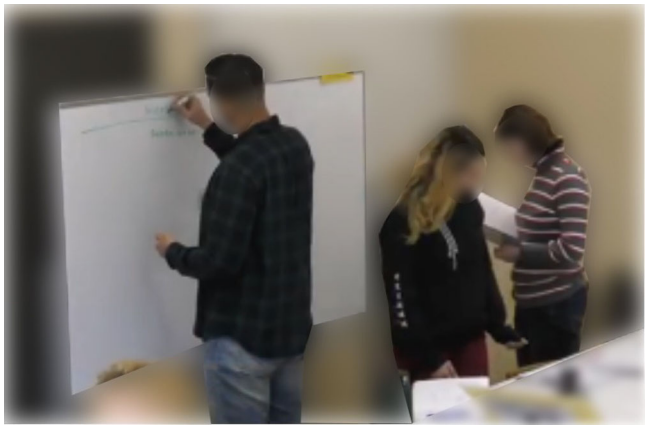

FIG. 4. Drake writes "heating" above the horizontal line he's drawn on the whiteboard. Image description: Drake stands facing the board with a whiteboard marker in his hand. He has started to draw the Energy Interaction Diagram. Paris faces away from the board, toward the table, and is looking down at the table. Gail faces the board and looks down at a notebook.

look down at their lab manuals, presumably reading the questions. Then Paris makes a bid for what should be the initial and final conditions in their EID:

14. **Paris**: So I think the initial is, initial final are both liquid, right?
15. **Drake** (pointing down at paper): Um.
16. **Paris**: Cause you're heating it but it doesn't say you're heating it to like a gas or it starts at a solid. Just says [both are water].[5]

[5]In transcript chunks, … indicates a pause in speech, words in square brackets are unclear and represent our best guess as to what was said, and words in parentheses are gestures or notes. When speech was inaudible or could not be transcribed, this is indicated by (inaudible).

In this brief exchange, we understand Paris to be saying that she knows the initial and final states are liquid because the problem does not say that the phase changes, and it refers to water. Drake writes "liquid" on the board over the leftmost vertical dash on their line, reflecting Paris' bid.

Gail then speaks while Drake is writing:

17. **Gail**: Oh, we're making the heat capacity (inaudible), trying to determine its heat capacity. [Weren't we doing this] (inaudible).
18. **Paris**: Determine how much water [is inside there]?
19. **Gail**: Or no we are trying to raise it to one, we're trying to raise the temperature of the water by one degree Celsius.
20. **Paris**: Because that's how you measure…

In this snippet, Gail names the group's task as "trying to determine its [the water's] heat capacity," which Paris revoices as trying to "determine how much water is there." One possibility is that Paris is thinking of the mass dependence of heat capacity. Gail rebuts Paris' proposal, offering instead that what they are trying to do (in determining the heat capacity) is to "raise the temperature of water by one degree Celsius." This is the formal definition of heat capacity—how much energy (or heating) it takes to raise the temperature of an object by one degree Celsius. Paris affirms Gail's suggestion, adding that they would do that "because that's how you measure…" Drake simultaneously responds to Gail, beginning shortly after Paris starts answering in line 20:

21. **Drake**: Oh, so it will always be liquid. Because um, because that's the only way temperature changes. It won't change between liquid [and gas].
22. **Gail**: Well if it, if it was at 99 degrees, and we raise it to 100 then it might? (Might is inflected up, and Gail's gestures indicate this is a question.)
23. **Drake**: Yeah. Yeah.
24. **Gail**: Or if it's more than 100, then.

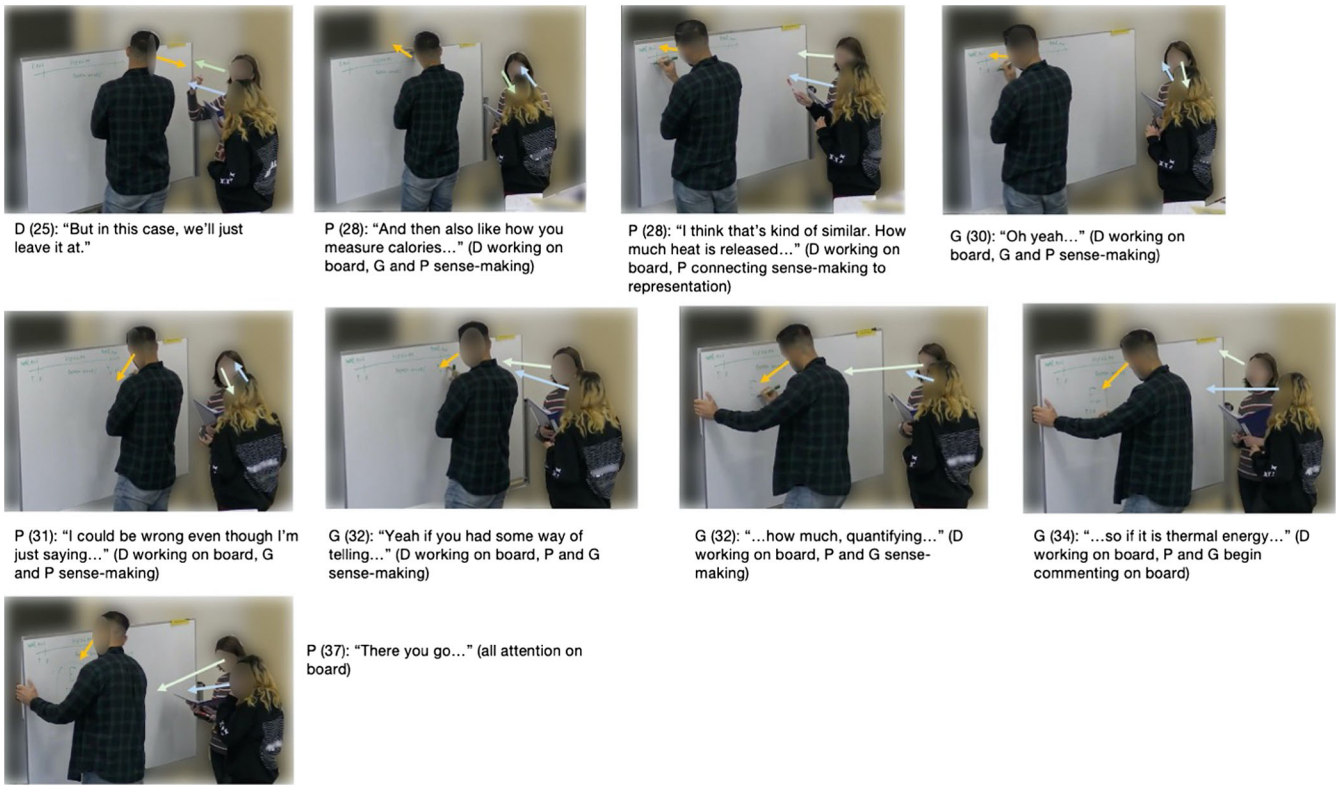

FIG. 5. Paris and Gail increasingly turn their attention to the whiteboard as they sense make. Arrows indicate participants' gaze. Image description: A series of images that analyze Drake's, Paris', and Gail's gaze. In the first image, Drake is facing Paris and Gail and they are looking toward him and the board. In the second image, Drake looks at the board and Paris and Gail look at one another. In the next four images, Paris and Gail alternate between looking at one another and looking at the board, and Drake looks exclusively at the board. In the final three images, Paris and Gail's attention is more stably on the board.

25. **Drake**: But in this case we'll just leave it at liquid. (Starts annotating end of arrow.)
26. **Paris**: I think in this case you're assuming it sits there.
27. (Gail nods at Paris.)

We interpret Drake's move in line 21 as a bid to turn the attention of the group back to the representation he had begun to draw on the whiteboard—specifically, to determine what he should label the final conditions on the right vertical notch in the arrow at the top of the EID. He may be building on what Gail has said in line 19 or what Paris said in line 16; his justification for why the water remains a liquid is that temperature changes only happen within phase.

In line 22, Gail challenges Drake's claim from line 21, arguing that it is possible for the temperature to increase *and* for the phase to change, if we are at the edge of the liquid range, and it's also possible for the temperature of other phases of matter to change ("if it's more than 100"—i.e., gas can also change temperature, so "temperature change" does not map directly onto "liquid"). Drake's response in line 25 is at once an acknowledgment (he does not disagree) and an assertion (in this case, we will leave it as liquid). Paris' response in line 26 seems to more directly engage with Gail's ideas, perhaps saying "that may be true but the question seems to be making a different assumption."

Paris then returns to sense making about how to measure heat capacity (lines 17–20), proposing something that resembles calorimetry. Gail engages with her, while Drake works independently at the board:

28. **Paris**: And like also how you measure calories is what you eat you measure the heat it is given off, when it's burned. So I think that's kind of similar to how much heat is released when you heat up this water and that's the capacity.
29. **Gail**: Ohh, yeah! Or how much heat (inaudible).
30. **Iris** (in the background): Two more minutes! It's okay if you're not done, but two more minutes.
31. **Paris**: I could be wrong even though I'm just saying (inaudible, gestures hand out, bracing) from like, college, I know, right.
32. **Gail**: Yeah If you had some way of telling how much, quantifying how much energy you're putting in, [something like that].

While Gail and Paris talk, Drake continues writing on the board. Around line 28, he is labeling the end arrows: "$T_i = x$" on the left, "$T_f = x + 1$" on the right. By line 31, Drake is constructing the "energy bubble," writing E_{th} for

thermal energy. As Paris and Gail talk, their gaze shifts between one another and the board, with increasing attention to the board as their conversation proceeds (Fig. 5).

By line 32, their gaze is stably on the whiteboard (Fig. 5), and Gail shifts her attention from the conversation that she and Paris are having and comments on the board. Paris follows suit, picking right back up where they left off in lines 21–27, referring to phase change:

33. **Gail**: So if it is thermal energy [here] then.
34. **Paris**: There's no bond energy because there's no phase change, right?

They turn their full attention to what Drake has been doing with an affirmation issued by Paris, followed by an addition suggested by Gail:

35. **Paris**, looking at board, where Drake has written x for the initial temperature: There you go, you could use variables instead of making [random].
36. **Gail**: I mean [you could make it] degrees Celsius.

Drake continues to draw, without responding to Paris or Gail. Paris looks down at the worksheet (where the problem is written), and Gail continues looking at the board. Drake pauses, presumably finished. At this point, the EID has "heating" (process at the top), with a timeline that includes "liquid" and "$T_i = x$ " on the left and "liquid" and "$T_f = x + 1$" on the right. Drake has also written "system = water" over a dotted oval, indicating that the system is open, with an arrow crossing the system boundary, labeled Q. Within the system boundary is a single energy bubble, with "E_{th}" at the top and an upward arrow, indicating that thermal energy increases. The remainder of the text is hard to see, but we think he has also written "$T_i = x$ " and "$T_f = x + 1$" in the energy bubble, and has written "$Q = \Delta E_{\text{th}}$" to the side. As Drake pauses, he turns toward Gail and asks for endorsement of his work.

37. **Drake**: Right there. That's good, right?
38. **Gail** (moving inward toward Drake's drawing): I would say degrees you have degrees Celsius right here (pointing).
39. **Drake**: (inaudible) should say plus 1 degree Celsius.
40. **Gail**: Yeah, um.
41. **Drake**: [Usually] you don't put units on the variables. Or do you?
42. **Paris**: No.
43. **Gail**: Umm I mean I can say that it's like.
44. **Paris**: Once you figure out the variables you can put them in, because we don't know yet.
45. **Drake**: Yeah. No well we know the variables. I mean we know the unit for the variables.
46. **Paris**: So you're saying this is Celsius? (pointing)
47. **Drake**: Yeah. I don't know how to write that.
48. **Iris**: Alright, take fifteen seconds to take a seat and then we're gonna talk.
49. **Paris**: You can put in parenthesis 'in degrees Celsius.'

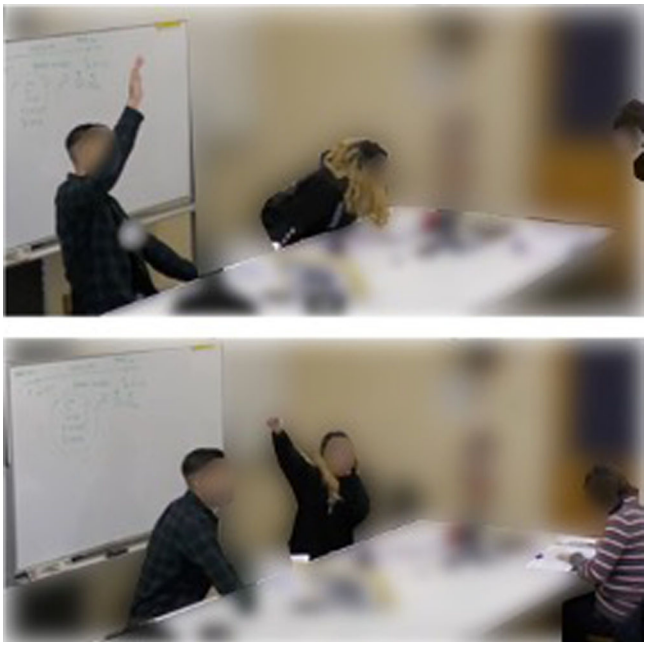

FIG. 6. Drake raises his hand to share out for his team (top image). When he lowers his hand, Paris draws attention to him by pointing (bottom image). Image description: Two images: In the top image, Drake and Paris are seated at the table and Gail is taking a seat opposite them. Drake is raising his hand and Paris and gail are gazing down at the table. In the bottom image, Paris is pointing at Drake and Drake's hand has lowered. Drake is gazing in the direction of the instructor. Gail is looking down at her notebook, which is on the table.

Drake writes what Paris bids on the board. Iris, the instructor, calls the class to attention, saying, "Alright, does anyone want to take us through their representations?," and Drake immediately raises his hand (top image, Fig. 6), while Paris and Gail are still settling in. Iris then indicates the presentations will start with the focal group, saying, "So we are doing three and four. So someone tell us what it is that they did and then answer the, respond to the prompt." Drake puts his hand down, and Paris immediately draws attention back to him by pointing at him (bottom image, Fig. 6). Iris calls on Drake:

52. **Iris**: Drake?
53. **Drake**: So we used variables…
54. **Iris**: Would you remind us what you were supposed to do though?
55. **Drake**: Yeah, we are on number three and we did the open system for the energy interaction diagram.
56. **Iris**: And what process are we modeling?
57. **Drake**: Uh heating.
58. **Iris**: Okay.
59. **Drake**: Yeah. Right?
60. **Iris**: Yes.
61. **Drake**: So we are trying to use a energy interaction diagram to try and found out, uh, the heeeeaaaat capacity, right? (Drake backs up in his chair and

orients to board as he explains; Paris is looking at the board, Gail is writing or looking down at her notebook.)

62. **Iris**: Yes.
63. **Drake**: Yeah. So what we did was used variables because we don't really know what temperature we are at, but, um, we only included thermal energy, because in this case we want to see a degree change, and the only time you see a degree change when you are on the uhh slope, where there is no, there is no, there's only a temperature change, and there is no phase change. So we knew it was a liquid. We knew it was in the range of like 0 degrees to 100 degrees. I didn't know what to put, so I just put x, I put x for whatever temperature we were at. And our T initial is x and we are using Celsius. And we used $x + 1$ degree Celsius (stands, gesturing at the board) for the T_{final} and uh we use thermal energy in an open system. because we are adding energy in, er, heat in, and our thermal energy goes up, and you see our initial and finals here. And that's how we got Q equals delta E_{th}.
64. **Iris**: Right, and you know, I really like how you're like 'one degree.' Why did you say one?
65. **Drake**: Uh, cause that's what we were looking for in the, um, is this heat capacity or specific heat?
66. **Iris**: Well, both of them.
67. **Drake**: Yeah.
68. **Iris**: Regardless of whether it's specific heat or heat capacity, both of those things have in their definition that you're raising it one degrees Celsius. Cool.

In this final snippet, Drake presents the EID, explaining the decision points for each part: they included variables because they didn't know the temperature; they chose liquid because they need to see a temperature change; they chose an open system because energy is being added. Iris' move in line 56 draws attention to the EID, pressing for Drake to lead with the first part of the diagram (the process being modeled). In lines 64–68, Iris affirms Drake's presentation, reflecting back that the process modeled in the EID is correct and uses the correct definition of heat capacity.

V. ANALYSIS: MAKING WHITENESS VISIBLE

In this section we use the analytic markers that we named in Sec. II to substantiate our claim that *whiteness is reproduced in this physics classroom episode* and to identify some of the physics tools, practices, and disciplinary values that reify and reconstitute it.

A. Centering

Whiteness as social organization normalizes and rewards the creation and maintaining of a well-defined center and margins. In this episode, classroom activity is organized in such a way as to make normal the centering of Drake and the representation he constructs, over and above the sense making that Paris and Gail are doing. Evidence for this is in

1. *Drake's attention*, which is directed toward constructing the energy interaction diagram and away from the sense making that Paris and Gail are doing. Following the instructions given by the lab manual, Drake initiates the interaction by structuring the discourse around the EID that he has started to draw (lines 1–4). After some side talk about portion sizes in the U.S., Paris and Gail begin to sense make about the problem (lines 17–20); they seem to be working to answer a conceptual question: what is heat capacity, and what does that mean for what we are doing. In line 21, Drake directs their attention back to a question that needs answering for him to continue constructing the EID. In the exchange from lines 21–27, Gail contributes a clarification to a universal statement Drake makes about temperature and phase changes. Drake does not take up the opportunity to construct or refine that statement, but again directs the conversation back to what is needed for the EID. Paris and Gail return to sense making about the problem, and Drake independently completes the representation on the board. When he presents their work to the class, the representation is the touch point. In short, the representation he is constructing is the center of Drake's attention and activity in this six-minute episode.
2. *Paris and Gail's attention*, which is divided; even as they engage in their own sense making, they also attend to Drake and the representation he is constructing. We see this in their turning their attention to Drake's question in line 21, in their gaze throughout their collaborative sense making in lines 28–34 (they are talking to one another but looking at the board; see Fig. 5), and in their turning their attention to Drake's representation in line 35 without any overt bids (their attention is now on the board and the EID, without their overtly negotiating to shift it there).
3. *The instructor's attention* in the large group share-out, which is directed to Drake and the representation that he constructed. The EID structures the share-out; in fact, Iris' initial question to the class is "Does anyone want to take us through their representations?," and she redirects Drake to name the process in line 54, which is the first step in constructing an EID [74]. The share-out is led by Drake; he volunteers by raising his hand, and Paris affirms this volunteering by calling attention to him when he puts his hand down (Fig. 6). During the share-out, the instructor's questions and affirmations are in response to Drake and the EID. The substance of Drake's share-out is the representation and how

FIG. 7. Gail moves inward to comment on the EID. Image description: A series of five images of Drake, Gail, and Paris standing at a whiteboard. Drake is directly in front of the Energy Interaction Diagram he has drawn, on the left side of the board. Over the series of images, Gail moves inward toward the diagram and then back, but does not move all the way back to where she was standing. Paris remains to the right.

> decisions were made about what to include or not include; nowhere in this share-out are Paris and Gail's sense making amplified, even as remnants of that sense making appear in the representation itself—e.g., Paris and Gail's sense making about what heat capacity means in line 19 seems to shape Drake's determination that "it will always be liquid" and then his labeling of the final condition as such in the EID. In this sense, Drake's construction of the EID relied (in a process-theory-of-cause [70,76,77] kind of way) on Gail and Paris' sense making, even as the credit is centralized in him.

Importantly, as we will argue in Sec. V D, the EID draws attention to itself, and the system rewards actors for giving it their attention.

Further, though the centering of the EID is relatively stable throughout this episode, the actors' proximity to the center shifts over time. More specifically, Drake maintains a position close to the center; Paris maintains a more marginal position; and Gail moves between center and margins as the episode progresses. Paris makes substantive contributions throughout—e.g., she names the initial and final conditions as liquid in lines 14 and 16, and it is in response to this that Drake writes "liquid" on the left side of the timeline in the EID. However, she often frames her utterances as questions, indicated by an upward intonation at the end of her sentences, and Drake and Gail act as filters for her contributions—Drake by deciding if and how to reflect them in the EID and Gail through discourse, like when she corrects Paris' statement of the problem in line 18 and clarifies the conditions under which Paris' suggestion would work in line 32. Gail also moves toward the center when she issues challenges to Drake's assertions in lines 21–27 and recommendations for the EID in lines 37–49. Notably, Drake seeks *Gail's* approval of the EID he's drawn in line 37; when he says, "That's good, right?," he seems to be talking to her, and she responds by moving physically inward, toward the EID (Fig. 7). She moves in front of Paris, toward Drake and the EID, and, after issuing the statement in line 38, moves backward but maintains a more central position physically, standing in front of Paris (final shot in Fig. 7). Importantly, the discursive mechanism through which Gail moves inward is typically assessment or critique, consistent with norms of competitive argumentation in physics [78,79].

We argue that it is whiteness as social organization that makes Paris, Gail, Drake, and Iris' behavior sensible. Within whiteness as social organization, there is a center that has been ascribed transcendent value; all else is, in effect, marginal. In this context, it makes sense that the EID, standing in for correctness and/or physics, will capture the attention of the actors, and it also makes sense that the person closest to it (by consensus or by force) would also receive the most attention. Activity that is not seen as productive toward these ends would also be seen as less valuable, highlighting ways in which whiteness and capitalism intersect. Whiteness makes "normal" this interactional unfolding, prompting questions like, "What else could have been done?" Importantly, here, whiteness masks that: there are many ways (not just Drake's or even the prescribed, endorsed way) to construct the EID, many representations for the energy dynamics of this scenario, many ways to understand the heating of water (including those outside of traditional physics), etc. The point is not that Drake's EID *has no value;* the point is that the space has been organized such that the EID and those closest to it have value at the exclusion of all else.

B. Meritocratic and race-evasive frames used to justify the center

Within whiteness as social organization, meritocratic and other frames of race-evasive ideology are used to explain or justify the creation or maintaining of the center. Such frames recuse dominant actors from responsibility for the outcomes of white supremacy; narrating success solely in terms of hard work or meritorious qualities treats outcomes as natural and does not recognize the role of white supremacy in shaping who is materially and ideologically "successful." Because these frames help keep whiteness intact, the use of these frames is often *rewarded*, and the use of frames that point to whiteness is often punished [3,39], such that it can be difficult or nonsensical for actors (especially white or dominant actors) to understand centering as anything other than meritocratic.

In stimulated recall interviews about this episode and about her experience in the course, Paris draws on

meritocratic and naturalization frames to normalize Drake's centering. Bonilla-Silva [3] defines naturalization as "a frame that allows whites to explain away racial phenomena by suggesting that they are natural occurrences," as "just the way things are," rather than driven by white supremacy. That Paris marshals meritocratic and naturalizing frames to explain Drake's centering is further evidence that this episode reproduces whiteness as social organization.

For example, commenting on a second whole-class conversation that we had clipped, where Iris calls on students in sequence to answer questions about a different scenario, Paris describes how share-outs typically go in their course: "She'll [Iris] usually call on people. People are choosing to raise their hand and answer, typically the same three or four people." When pressed to elaborate, Paris continues:

> *"Yeah, there's about two or three people in the class. I think there's twenty total or something like that. There's, yeah, two or three, they're the ones that raise their hands and answer the questions throughout the entire semester. It's very rare to get anyone outside of those two or three. But they're pretty smart. They answer, usually in detail, especially now that we've gotten to the really, really hard stuff. This [referring to the video she watched] is more of the easier stuff at the time. But they answer it very well. Then I'm usually writing down everything that they are saying, if [the instructor is] like, 'Yes, that's correct.'"*

Here, Paris describes the social organization of her physics class: the same two or three students volunteer and then are selected to share their ideas with the whole class. Notably, Paris sense-makes about this pattern using a meritocratic frame: these students volunteer and are called on because they answer questions well, answer in detail, and are really smart. In fact, Paris *appreciates* the centering of these students, which helps her to get the right answer, the thing that has been ascribed value by whiteness, over and above other things.

When asked if she thinks that having the same three people volunteer and be called on is typical or atypical for a physics class, Paris responds:

> *"That seems typical to me. I think it goes back to also people's personalities. Some people are more maybe introverted, and they know the answer, but they don't want to, maybe they're just too shy. Or maybe they don't [know the answer] and they don't want to know and they're just trying to pass the class because they have to. But I think [the students who volunteer] are the students that are genuinely interested in learning the subject material and just, you can tell that they study each week. Everything adds up to-, eventually connects to each other. Yeah, they can answer it really, really well, and they have the confidence. Like I said, when I know, I will raise my hand."*

Here, Paris layers personality, introversion, interest, hard work, and confidence onto her naturalization of the centering of a small number of students in her class.

In reflecting specifically on the video episode we analyze in this paper, Paris shares why she nominates Drake for the large-group share-out:

> *"Usually, it's the person that understood it the most that we will nominate. If I feel confident and I know the answer, I will raise my hand and be like, 'I can explain this in detail very confidently, very bravely.' Then if not, then I know who can, and Drake was the one who, like I said, he took the wheel. He understood this, therefore would be a great leader for the team to speak for all of us."*

When asked what told her that Drake understood the problem, Paris offered a few different reasons:

- "…the fact that he'd taken physics prior to this."
- "He also demonstrated that he kind of understood it when he was talking."
- "He was inputting the variables, he knew what variables to put. He seemed like he knew really well how to do that problem."

In Paris' narration of Drake's understanding, then, representational fluency plays a role in the merit assigned to him, as does the cultural capital [80,81] he has accumulated from moving in physics spaces before.

Also notable is Paris' use of the term "he took the wheel" to describe Drake's behavior in this episode. She goes on to elaborate a few moments later, saying,

> *"In this particular video, like I said, I think Drake took the wheel. He doesn't always, but sometimes he'll go ahead before we get consensus and put it up, his answer, and do everything without talking to us. He rarely did that. But yeah, in this video, this was one of them where he kind of did that. So that made it a little bit … but you know, I was making sure that me and Gail had a say as well. Then once I had mentioned that or anything he was like, 'yeah, yeah, yeah.' Just has to be reminded."*

Though she says that he "rarely" puts his answer up "without talking to us" as he does in this video, she answered the follow-up question—"Is the interaction you just watched…typical for your group or atypical?"—by saying it was "pretty typical." She continues, saying that she "think[s] it's also just people's personality. But anytime I said something, it was like, 'yeah yeah yeah.' And then he'd switch, letting everybody kind of have a say."

Here, Paris uses language that points to Drake's having control of the center (and, perhaps also, being controlled by

the center), saying that he "took the wheel," and she describes situations in which Drake restricts access to the representational space ("he'll go ahead before we get consensus and put [his answer] up…and do everything without talking to us"). In immediately subsequent and immediately preceding talk turns, she: describes this behavior as rare and then typical; makes sense of Drake's behavior in terms of his personality and absolves him, saying that he would "switch" into a frame of "letting everyone have a say" when reminded; and makes sense of his centering in this episode in meritocratic terms. At the same time, she identifies ways that she is challenging the default social organization, by "making sure that [she] and Gail have a say," illustrating that as she is simultaneously an actor recreating whiteness as social organization, she is also exercising her agency to loosen its hold on her group [64].

In both her interview and the episode we analyzed, we see Paris navigating some of the tensions inherent in whiteness as social organization. Whiteness promises security and success (in a capitalistic system) to those who ally themselves to it by centering the transcendent thing of value. Paris sees that this is the bid and answers to it, by, for example, nominating Drake to share, sense making about his centering in meritocratic terms, and attending to and writing down the ideas of her peers that get Iris' affirmation in class. But she is also naming some of the *costs* of whiteness here, such as not being heard or reflected in the outputs of her group. (We see this also in line 21, when she calls in authority for her claims to Gail.) These tensions and costs are part and parcel of the fragmentation [17,18] experienced within whiteness, or the need to split oneself in order to fit in. We turn to an additional example of this next.

C. Constraints on folks' agency in deviating from whiteness as social organization, even if their stated values would press for a different social organization

In part because whiteness as social organization uses mechanisms of control that enforce the center, actors can have limited agency to deviate from it, even when their values are better-aligned with a different social organization. In a stimulated recall interview, when asked to describe her pedagogical approach, Iris led with

> *"My approach is instead of lecturing I'm more interested in students collaborating and working with each other, and doing science themselves as opposed to me telling them about science….When I'm teaching the class I really try to not tell them what's going to happen. I want them to observe a phenomenon for themselves. I might help them ask a particular question but eventually we want them to ask the particular questions. Then we start usually by having students tell a story that they might put up on the board in their small group. Then we would share out as a whole class…But overall in an ideal situation I want the students to drive the class. I want the students to drive conversations and to do the sense making and explaining."*

Here, she lays out a vision for a nonhierarchical social organization of the classroom, in which students are doing authentic science, constructing stories that are grounded in their own observations of phenomena, and rich in sense making [82–84]. She layers on a model of participation in which students share the floor, saying,

> *"I feel like if it's an ideal scenario I've done norm setting at the beginning of the semester to kind of rein in students who take up a lot of space and maybe talk over other students."*

In the focal episode, we see that the share-out is structured around the correct answer or representation, over and against Iris' stated priority on supporting students in collaborative sense making. Gail and Paris are sense making about the problem and drawing on phenomena they have observed in other courses (e.g., calorimetry), but the share-out focuses on what the instructor has "told them about science" (in the form of EIDs) and gives the floor over to a student that "takes up a lot of space." This tension —between the instructor's values and the social organization of her course—is visible to her. Interwoven in her reflections about her approach are tensions she faces in trying to enact this pedagogy, including not being able to "get the students to come to the conclusions [she] want[s] them to come to by themselves," facing time constraints and trying to balance a busy teaching schedule, students' unwillingness to participate in whole-class discussions, and her perceptions of students' anxiety.

We would argue that Iris' agency is constrained by whiteness. The *outcome* expected of her teaching is students who can access the center defined by physics. Though she values a nonhierarchical classroom organization, her efforts to cultivate this seem to jeopardize what whiteness enforces as valuable (materially and ideologically): prioritizing correctness, as defined by physics. Further, the *tools* at her disposal—e.g., the EID—reify whiteness in ways that limit available social organizations. We discuss this further in the following section.

D. Mechanisms of control that enforce the center

Whiteness as social organization is maintained, in part, by mechanisms of control that enforce the center and discipline those who deviate from it [2,42,51,53]. This "discipline" takes forms varying from physical restraint or violence to microinvalidation and ostracization (e.g., someone is made to feel like they are doing something wrong, unacceptable, or abnormal) [53]. People only need to feel the *threat* of this discipline for it to shape their behavior;

they need not face or have faced these consequences. The mechanisms of control we identified in our analysis are an answer to the question, "What reifies or makes possible whiteness as social organization in this episode?"

We identified (at least) five mechanisms of control in this episode and the associated stimulated recall interviews. These mechanisms are not necessarily distinct or deterministic; they act in concert with one another and with other aspects of *this* context to co-produce and maintain whiteness as social organization. Importantly, in saying that these mechanisms function to reproduce whiteness in this context, we have not said that they are not useful or not true. Saying, for example, that money is one mechanism in the reproduction of capitalism does not make money un-useful or untrue; within capitalism, money is both useful and real, and necessary to come out on top, so to speak. Looking at money in context is part of looking at how capitalism functions; that is what we are doing here.

1. Energy interaction diagram

The first mechanism of control we identified is the representation itself, mediated through the task and instructor's instructions. In this episode, the EID disciplines the discourse and shapes its form, and the person who controls the representation (Drake) also controls what goes in it, and thus what parts of the small-group conversation get amplified to the class. For example, Gail makes a number of bids throughout the dialogue for how the process should be represented, including clarifying the state of matter that the substance is in (lines 21–27) and naming the units of measure (lines 37–52). Drake declines Gail's bid in the former case ("we'll just leave it at liquid," then labels the arrow) and presses to exclude the units ("usually you don't put units on the variables, or do you?") in the latter, ultimately acquiescing to a compromise proposed by Paris that includes Gail's bid in a parenthetical annotation on the diagram.

Thus the representation does not act neutrally, but is central to Drake's access to and control of the center: he accesses the center by taking control of the representation, and he maintains control of the discourse and the sharing-out by maintaining control of the representation. Not only this, the representation *suggests* a social organization and discursive frames that reify and maintain whiteness as social organization. Paired with other mechanisms of control (like the use of whiteboards and the structure of schooling), it organizes activity around itself, makes it possible for a single person to maintain control (and makes natural ways to keep others from gaining control), centralizes the credit in the person with the most access to it, and suggests discursive frames that make this seem normal (he understands it, he was the closest to it). In short, the representation co-constructs whiteness as social organization, making sensible (and even benevolent) its own (and its author's) centering: the representation is the *thing* of value to construct—a single, correct, endorsed thing—and the entire group will be granted social and cultural capital (albeit differentially) if they do it "correctly." In this interaction, the centering of the representation (and Drake) marginalizes the activity of sense making that Gail and Paris are engaged in, even as this sense making is important to what is ultimately reflected in the representation.

2. Physics values

We contend that the representation's power and capacity to reify whiteness as social organization relies at least in part on its embodying a set of values that are endemic to physics. Together, these values construct an epistemological center—i.e., communicate what counts as knowledge and knowledge construction in physics (and what does not)—which produces an ideology of epistemological superiority and, within that, epistemicide [45,53], or the "extermination of knowledge and ways of knowing" outside the center [37], (cited in Ref. [45]).

In this episode, specific values within physics contribute to the centering of the representation and of Drake. Namely, physics values abstractness and disembodiment [13,78,85,86]. The centering of representations, which are abstractions, reflects these values. The abstractness of the representation allows for—in fact, makes natural—abstracted ways of being in relationship with people, normalizing and even rewarding the co-opting or erasing of people's ideas and experiences, while simultaneously centralizing credit for the influence of those ideas in a dominant other. Bang [45] names this "subject-object relations" (in comparison to subject-subject relations) and ties it to settler colonialism, saying that "[t]he centrality of subject-object relations…has perpetuated nature-culture relations that reflect human domination and entitlement." In this case, the abstraction makes normal the appropriation of Paris and Gail's contributions—it makes them invisible, in fact—and allows for the accumulation of credit in Drake. It also narrows the scope of possible contributions to ones that can be represented (abstractly) in this particular form.

In addition, the EID Drake presents does not show its history—it presents as *ahistorical*—which reflects and reifies the "culture of no culture" myth in physics [78]. Ahistoricity supports revisionist versions of history that fuel white racial ideologies, by centering white perspectives on historical events, downplaying white violence, disconnecting current racial violence and trauma from its long history, and constructing mythologies where domination and centering appear "God-given and right" [36,45]. In this episode, the ahistoricity of the EID presented by Drake erases the collaborative contributions of Gail and Paris and makes it difficult to challenge or analyze the nature of their interaction, since it is not reflected in the EID. Further, the history of EIDs (and the model of energy they reflect) is not

visible in the tool itself, which maintains the mythology that physics is a "culture of no culture."

Finally, the priority within physics to capture the dynamics of the physical world in a small number of principles—what we will call *unification* here—contributes to the power that this representation holds. With unification, the goal is to get to the smallest number of principles that can explain as many physical phenomena as possible. Organizing around unification means that many things follow from those most basic principles, such that getting these basics wrong can feel like a scary prospect. Paired with the culture of schooling, where power is conferred and communicated through grades and qualifications [80,81,87], and where grades and qualifications are often assigned on the basis of correctness, unification as a value acts to constrain actors' agency and discipline their attention, toward the physics canon and physics practices (as in Iris' case). In this episode, unification is communicated within the representation itself, whose constituent parts are coordinated. It is also communicated by the topic: energy is a foundational concept, and the conservation of energy (reified in this representation) is a central principle.

3. Whiteboards

Entangled with the above is the use of whiteboards as a primary pedagogical tool. Though whiteboards have been shown to have a number of affordances when they are used as a collaborative tool that all members have access to [88], in this episode, they also play a role in reconstituting whiteness as social organization. In particular, whiteboards display written information for public consumption; they draw attention to themselves and in this case support the centering of an abstract representation and the person standing next to it, presenting. They collaborate with white organizational culture [89], where ideas and experiences gain value (become more central) when written down.

4. Gendered social norms

In this case, the whiteboard also collaborates with classroom expectations and gendered social norms to facilitate Drake's centering and whiteness as social organization, making certain discursive and spatial moves risky or nonsensical. For example, after Drake has grabbed a whiteboard marker and begins to draw, the available next moves for Gail and Paris are limited: they can grab additional whiteboard markers and begin drawing elsewhere, or work to take the marker away from Drake, but these moves may be seen as uncollaborative (they are supposed to construct a *group* representation) or out of line, especially in patriarchal culture. Manne [90] distinguishes between sexism and patriarchy, saying that sexism is "the branch of patriarchal ideology that *justifies* and *rationalizes* a patriarchal social order," whereas misogyny is "the system that *polices* and *enforces* its governing norms and expectations." She goes on to say that

> *"In this economy of moral goods, women are obligated to give to him, not to ask, and expected to feel indebted and grateful, rather than entitled. This is especially the case with respect to characteristically moral goods: attention, care, sympathy, respect, admiration, and nurturing."*[6]

In this episode, the patriarchal social order would frame Gail and Paris' role as offering Drake "attention, care, sympathy, respect, admiration, and nurturing," and communicate a threat of consequences were they to disrupt his claiming of the center. The fact that I (A.D.R.), a white woman, giggled when writing that "Gail and Paris could work to take the marker away from Drake," is concrete evidence of these patriarchal norms. This seems *silly*. But I did not giggle—or even blink—when Drake stood up, quickly grabbed a whiteboard marker, and began writing, all without negotiating this with Gail and Paris.

Patriarchy makes sensible certain assumptions about Drake's access to the center, similar to the way in which white supremacy makes sensible certain expectations of privilege [39,91]. Evidence of these assumptions in this episode are in Drake's grabbing the whiteboard pen and his raising his hand to share without consulting with his group. This is not contested and is in fact affirmed by Paris. Here, then, patriarchy is co-participating with whiteness to structure and enforce centering and marginalization.

Notably, Crenshaw's definition of intersectionality [92] can lend additional analytic insight into the centering and marginalization that is happening in this episode. In landmark Black feminist scholarship, Crenshaw illuminated that a "single-axis framework" (e.g., only race, only gender) when applied to discrimination "erases Black women." She showed that "in race discrimination cases, discrimination tends to be viewed in terms of sex- or class-privileged Blacks; in sex discrimination cases, the focus is on race- and class-privileged women." Intersectionality would suggest that Gail (white woman) and Paris (Hispanic woman) may have very different experiences within a patriarchal system, with different consequences for challenging the norms and expectations. We see this reflected in the roles that Gail and Paris take: whereas Gail occasionally challenges Drake's representational choices, moving toward the center as she does so, Paris takes an almost-exclusively supportive role, affirming Drake's choices and sometimes even smoothing over disagreement between Drake and Gail (as in line 26).

[6]The quotations we have pulled from Manne's work point out the ways that patriarchy oppresses women and do not also include the ways that patriarchy oppresses trans, nonbinary, and other nonmale gender identities. The quotes also refer to gender solely in terms of men and women. In isolation, these quotes problematically reify a gender binary.

5. Structure of schooling

A central argument in the work of Bourdieu [80,81,87] is that schools serve to produce and reproduce the institutional conditions necessary for maintaining power relations. According to Bourdieu and Passeron, educational systems produce and maintain power relations by instilling values and knowledge (inculcation) that align with dominant culture and by perpetuating the conditions under which the arbitrariness (as contrasted with meritoriousness) of this dominance goes unrecognized. Further, they create *institutional structures* that support this work, such that the arbitrariness is further hidden in policies and practices that become "the way things are" in school. And "the way things are" in school are in a mutually reinforcing relationship with "the way things are" in society more broadly.

Bourdieu [87] plays this argument out with "academic qualifications." Academic qualifications make it possible "to relate all qualification holders (and also, negatively, all unqualified individuals) to a single standard, thereby setting up a single market for all cultural capacities and guaranteeing the convertibility of cultural capital into money, at a determinate cost in labour and time." Academic qualifications, having been "guaranteed by law," are "freed from local limitations" and thus

> *"the cultural capital which they in a sense guarantee once and for all does not constantly need to be proved… Once this state of affairs is established, relations of power and domination no longer exist directly between individuals; they are set up in pure objectivity between institutions…[which become] social mechanisms which produce and guarantee both the social value of the qualifications and the positions and also the distribution of these social attributes, among biological individuals."*

Lareau and Weininger [93] quote Bourdieu and Passeron's definition of cultural capital as "the educational norms of those social classes capable of imposing the…criteria of evaluation which are the most favorable to their children" (p. 588).

We contend that the structure of schooling—and in particular, mechanisms of control such as grades or academic qualifications—co-produces whiteness as social organization in this episode. These mechanisms of control and the cultural capital they confer make it seem *natural* and *right* that the representation be centered; it is, after all, what the question is asking for and what will help the actors "get a good grade." In school, knowledge is standardized—students are there to learn particular, endorsed things, with constraints on the time they have to do so. This system makes sensible Drake's inattention to Paris and Gail's sense making and his bids not to include certain things in the EID; both the EID and physics values participate with the structure of schooling to reinforce that the representation should only include particular things, and that what counts at the end of the conversation is what has been written down. They make sensible Paris' feeling of gratitude to students who volunteer to share their answers, even if only a few students are sharing, and Iris' experience of tension when students are holding the floor but answering questions incorrectly.

VI. DISCUSSION AND IMPLICATIONS

In the episode we analyzed in this paper, we observe an interaction in which Drake and the representation he is constructing are centered, and Gail and Paris' sense making and contributions are marginalized, both in their interactions within their (small) group and in the larger-group discourse. This social organization is co-constructed and co-maintained by at least five mechanisms of control: the EID representation, physics values, the use of whiteboards, gendered social norms, and the structure of schooling. Importantly, we would suggest that these mechanisms operate mostly invisibly; actors' participation in them is sensible and normal. At the same time, actors are (consciously or unconsciously) renegotiating their relationship to the center or expressing aspirations to change whiteness as social organization [51,53,64]. For example, Iris expresses a wish for her class to reflect nonhierarchical social structure, and has made a number of pedagogical choices that make this more possible, even if not actualized in this episode. Paris describes herself as "making sure that me and Gail had a say" in interactions with Drake, and Gail challenged Drake's assertions and made moves toward the center. Drake seeks Gail's approval at the end of the episode and makes discursive moves to distribute the credit for the construction of the representation (using "we" pronouns). That these aspirations and microchallenges did not fundamentally change the nature of the interaction or the social organization of the classroom in this episode points to the power and the institutionalization of whiteness. Even our notions of what collaboration means are shaped, epistemically, by whiteness.

Our goal in this paper has been to "make whiteness visible," in the tradition of Critical Whiteness Studies. In particular, we have sought to make visible how everyday physics classroom interactions reproduce whiteness as social organization, and how physics representations, values, and pedagogical tools play a role in this reproduction. That whiteness is "ordinary" in physics classrooms is not surprising, given critical race theory's assertion that whiteness is endemic to every aspect of U.S. society [7]. The ordinariness of whiteness' reproduction is not surprising either, given critical scholarship's emphasis on the invisibility and hegemony of whiteness.

It feels important to state explicitly that *physics as an epistemology* is not well-suited to assess arguments of the kind we have made here. That is, when we try to apply the historical knowledge-building practices of physics—such

as dismissing claims for which there are compelling counter-arguments or seeking the simplest form of an argument—to an analysis of social phenomena that are undergirded by power, we do that analysis (and the people who are its focus) a disservice. For example, when a physicist engages with the analysis of whiteness above and asks, "But is that really whiteness? I could see it being about patriarchy," or saying, "Just because mechanism functions this way in this context doesn't mean it does that in every context," and then *goes on to dismiss the analysis altogether*,[7] they are engaging in bad faith argumentation [94]. Arguing in bad faith gives the appearance of engaging with a topic while obscuring its core point and (often unconsciously) "come[s] from a place of not wanting to confront the actual arguments someone else is making." For example, the "cartoon strawmanner" is ready with counterarguments to something you are not actually claiming, and the "logic nerd" has "a very clear argument" with "multiple parts, each of which is impeccable and internally consistent" but misses the point that the argument is not about the validity of the logic, it's about "which logic we should follow" when making decisions [94]. Saying "but sometimes that mechanism does good things" is not only layering a binary good or bad lens onto our claim, it is also presenting a counterargument to something we did not claim.

In her book *So You Want to Talk About Race* [42], Oluo says, "While just about everything can be about race, almost nothing is completely about race." If the physics community is going to work toward dismantling whiteness, we have got to stop using physics epistemology to justify engaging in bad faith arguments that exculpate us from the responsibility of taking analyses of power seriously. We have to stop saying "you have not satisfied me yet," and start asking how to understand arguments about race on their own terms. So how do we know when something is about race? Again, Oluo provides guidance. It is about race if (a) a Person of Color thinks it is about race, (b) it disproportionately or differently affects People of Color, and/or (c) it fits into a broader pattern of events that disproportionately affect People of Color. In this paper, we have built from the work of Scholars and Activists of Color to articulate a framework that includes markers of whiteness as social organization, and then we have used a case from an introductory physics course to illustrate how one might "see" those markers in real time.

Watching whiteness as social organization unfold in real time is observing one gear turning in the machinery of whiteness. Scholarship on whiteness has identified whiteness as a racial frame (which includes bias), an ideology, a social organization, and an identity [5,35,36,46,54]. Whiteness is all of these things, and each manifestation makes the other more possible. For example, whiteness as social organization makes natural the development of a white identity that is rooted in supremacy: the environment affirms the exclusive and transcendent value of whiteness, thus affirming and supporting the development of a white identity that is rooted in supremacy. That white identity goes on to participate in the reproduction of whiteness as social organization, by, for example, making sensible claiming and holding the center in a social environment.

The impact of whiteness in physics classrooms cannot be understated. One outcome of enforcing a social organization with a (consistent) center and margins is *epistemicide* [45], or "the extermination of knowledge and ways of knowing" [37] (cited in Ref. [45]). We see glimmers of this in the data we have shared in this paper. In lines 28–32, Paris and Gail are talking about how to measure heat capacity, continuing from their conversation about what heat capacity is in lines 17–20. For the duration of this exchange, their attention is increasingly divided between the conversation they are having and the EID Drake is constructing on the whiteboard. They discontinue their conversation in line 33, without appearing to reach a resolution in their thinking, and begin commenting on the EID. Though this example does not, on the surface, appear as forceful as many examples of epistemicide in the literature [45,53,95], it is an example where one form of knowledge building was discontinued (or extinguished) in service of another.

Another outcome of whiteness as social organization is *fragmentation* [17,18], or "temporally splitting oneself to minimize cultural differences between oneself and other members of a community" [18]. Paris said (above) that she nominated Drake to speak on behalf of the group because he was "the person who understood it the most," but she also said that if she feels confident and knows the answer, she will raise her hand. In our interview with her, we asked her what needs to happen to make her feel confident. She answered that when she "can actually concentrate on the problem" at home and "authentically learn it before going into class," she will sometimes feel confident, and gave as an example when she "spent maybe five hours on this one just to understand it." That Paris feels she has to spend five hours on a problem before volunteering her ideas feels like evidence of fragmentation. Only when she is absolutely certain can she bring herself and her ideas forward; otherwise, she attends to the ideas of the small number of people who volunteer their ideas in class.

A central goal of our work is to develop critical consciousness [66] among physics instructors and physics education researchers. But we cannot stop there. In fact, Critical Whiteness Studies have been criticized for providing white folks a mechanism to continue in a state of perpetual learning, never moving into a state of antiracist

[7]The dismissal piece is key; bad faith arguments are *discounting* an argument on grounds that are peripheral. Asking these questions in an effort to more fully capture the power dynamics at play is a different thing.

action, and for recentering whiteness [24]. At the same time, white people's action needs to be informed by an antiracist lens [4,42,67,96], which includes an awareness of how whiteness is functioning in organizational spaces. We hope our work does not end with developing awareness but also inspires us to ask questions about what all of this means for classroom practice.

Though we feel that imagining more liberatory futures for physics should be a *community* conversation (not something we prescribe), there are frameworks from Critical Race Theory and abolitionist movements that offer a vision for a different social organization, outside of whiteness. For example, Banks and colleagues [38,97] offer a multidimensional framework for multicultural education that includes critiquing mainstream academic knowledge, rethinking the curriculum to center and celebrate multiple ways of knowing, and reorganizing school culture to resist white supremacy and rebuild around multiculturality. Grosfoguel [37] offers a second (related) possibility—where universality ("one defines for the rest") is exchanged for pluriversality. Drawing from the writings of Dussel [98], Grosfoguel describes a pluriverse as "a world where many worlds are possible," citing the possibility of both "a pluriverse of meaning and a pluriversal world." He notes that

> *"the call for epistemic pluriversality as opposed to epistemic universality is not equivalent to a relativist position. On the contrary, transmodernity acknowledges the need for a shared and common universal project against capitalism, patriarchy, imperialism, and coloniality. But it rejects a universality of solutions where one defines for the rest what 'the solution' is."*

If we ask ourselves what pluriversality and/or multicultural education might have looked like in this six-minute interaction between Paris, Gail, and Drake, we imagine the following:

- Paris, Gail, and Drake have a collaboratively defined, shared purpose with many solutions and approaches, including the possibility that the problems and questions could evolve as their work together did. This contrasts with Paris, Gail, and Drake having a shared task, defined externally ("one defines for the rest"), with a single correct solution and single endorsed representation of that solution.
- Attention and affirmation would be given both to the work that Drake is doing and the work that Paris and Gail are doing. It is not the case that the EID would "have no place"; instead, the EID would find a place among many valued ways of sense making toward a shared purpose. Among those valued ways would be experiences and ways of knowing that have not historically been recognized by physics (e.g., Eastern and Indigenous ways of knowing). These ways of knowing would be seen as sources of insight in a pluriversal conversation where many worlds are possible and matter.
- The situatedness of mainstream academic knowledge would be made clear, and the ways in which that knowledge has maintained and upheld systems of power would be critiqued, even as the knowledge could be held alongside other ways of knowing toward a shared purpose.

What we hope this imagining illustrates is that alternatives to whiteness as social organization are a *restructuring* of interaction and space; they are more than reworking or resisting *within* whiteness. For example, the suggestion earlier in the paper that Gail or Paris could wrestle the whiteboard marker away from Drake is not an alternative social organization to whiteness; it is a move that "flips the script" on patriarchy *within* whiteness as social organization. Freire [66] names this as a common response—the "oppressed become the oppressors"—and advocates instead for liberation in which both oppressed and oppressors become more fully human through praxis, "or [critical] reflection and action upon the world in order to transform it." Transformation and reworking of physics classroom spaces would include students having the liberatory agency to *reinterpret* the space and the content; they would be free to claim, not only conform.

We are keenly aware that these imaginings are challenging, if not nearly impossible, to manifest in a world where racism is permanent [4,99]. This feels particularly true within existing structures of schooling—with standards and time constraints—and within how we currently think about physics and physics instruction—with well-defined epistemologies and problem spaces. At the same time, Scholars, Teachers, and Activists of Color have been dreaming and creating for ages, and have invited us to join the movement for collective liberation. We want to dream together with you, toward physics teaching and learning as a "world where many worlds are possible."

As we dream, and as we wait for whiteness as social organization to be dismantled, we can work to reduce harm in the spaces we move and work. Harm reduction, as a framework, acknowledges that white supremacy, patriarchy, classism, fatmisia, transmisia, ableism, xenophobia, and myriad other systems of oppression infuse space and structures and are a part of our socialization. Paired with real-time repair, harm reduction provides support and accountability in the midst of this reality, inviting us to be humans in process and in community and offering space and support to see and respond to harm [100]. Harm reduction, then, lives in the interstitial space between not yet, without giving up on what could be.

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