Tracking Inequity: An Actionable Approach to Addressing Inequities in Physics Classrooms

Julie Christensen, Michigan State University, East Lansing, MI
Niral Shah, University of Washington, Seattle, WA
Nickolaus Alexander Ortiz, Georgia State University, Atlanta, GA
David Stroupe, Michigan State University, East Lansing, MI
Daniel L. Reinholz, San Diego State University, San Diego, CA

Recent studies reveal people from marginalized groups (e.g., people of color and women) continue to earn physics degrees at alarmingly low rates.[1-3] This phenomenon is not surprising given reports of the continued perception of physics as a masculine space[4,5] and the discrimination faced by people of color and women within the field.[6-8] To realize the vision of an equitable physics education, fully open to and supportive of marginalized groups, teachers need ways of seeing equity as something that is concrete and actionable on an everyday basis. In our work, teachers have found value in intentionally reflecting on their instruction and their students explicitly in terms of race, gender, and other social markers. We find they are then better positioned to build equitable physics classrooms. Without a focus on specific social markers, common obstacles such as color-evasiveness emerge, which obstruct the pursuit of equity in classrooms.[9]

We define *equity* in terms of what is fair, for particular groups or individuals.[9,10] We distinguish equity from *equality,* or the condition in which all groups or individuals receive the same treatment or allocation of resources. In our work with teachers, we focused on *equity* as it relates to student participation in classroom discourse and position *equality* as a "waypoint" toward equitable participation.[11] For students from marginalized groups, "equal" participation in classroom discourse may be insufficient or unlikely due to the history of marginalization these students have likely faced in their educational careers. Such inequity may be especially true given that marginalization often extends beyond receiving fewer opportunities for participation in classroom discourse, including other educational resources such as access to curricula that value students' cultural practices and pedagogies that support the development of students' identities as capable learners.[12,13] Therefore, we encourage teachers to consider past and contemporary forms of marginalization when determining standards of fairness. In other words, we recommend a "reparations-type" view when defining equity.

In this article, we present a three-step process involving a classroom observation tool called EQUIP (https://www.equip.ninja/), which teachers can use to identify and attenuate patterns of discourse inequity. We begin by describing EQUIP and how its design supports physics teachers in thinking about equity in terms of social marker patterns in typical teaching and learning situations. Then, we illustrate how our partner teachers used EQUIP in action research, as they sought to build equitable spaces for collaborative learning in computation-based high school physics.

EQUIP: Equity QUantified In Participation

EQUIP is a free open-source web app that provides teachers with quantitative data on equity patterns during classroom interactions.[11] EQUIP is designed to focus on equity in terms of students' discourse participation, both their actual participation and their opportunities to participate in classroom discourse. Participation in scientific discourse is crucial to learning,[14,15] and is important for both the contributor and other participants. Per the Diversity Statement of the American Institute of Physics, "diverse perspectives lead to better solutions to problems, better decision-making, and better outcomes." Given the importance for a diversity of perspectives and classroom discourse, EQUIP breaks down participation opportunities by both social marker and individual students and can be categorized by both their quantity (i.e., number of contributions during an interaction) and quality (e.g., fact/recall, explanation).[16] This process allows teachers to analyze

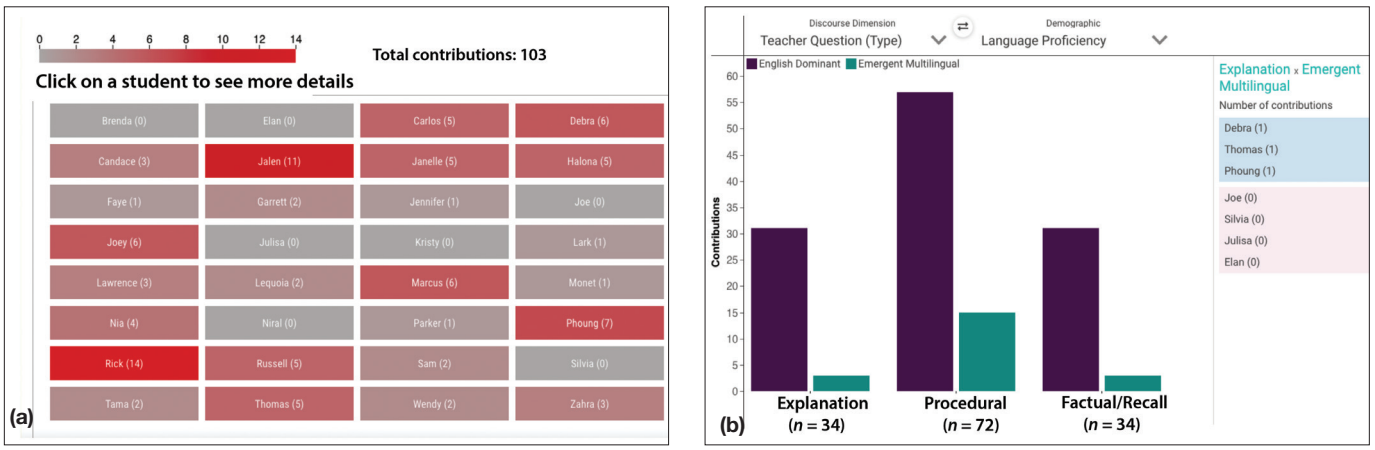

Fig. 1. (a) Sample EQUIP graph: heatmap showing individual student participation. (b) Sample EQUIP graph: type of teacher question distributed by language proficiency.

 DOI: 10.1119/5.0044392

how participatory opportunities get distributed in a classroom. For example, teachers can see if a particular student is dominating a discussion or if emergent multilingual students are not getting opportunities to contribute toward rich scientific explanations [Figs. 1(a) and (b)].

Teachers use EQUIP to code video recordings of classroom interactions (e.g., whole and small group discussions), often having an instructional coach or friendly colleague use EQUIP in real time while watching instruction unfold. EQUIP itself does not record or store classroom audio or video recordings. For each student contribution during a discussion, the observer codes their participation in the EQUIP web app. Over time, participation data accrues, which can then be analyzed through EQUIP's multiple data visualization platforms. We encourage teachers to remember that these quantitative data are best used in conjunction with qualitative data on equity and inequity, such as marginalized students' subjective experiences in classrooms. In other words, it is also important that students *feel* that they have fair opportunities to participate.

EQUIP is customizable, meaning that teachers can configure EQUIP to analyze equity patterns unique to their classrooms and school contexts in two ways. First, social markers (e.g., gender, race, SES) are easily modified. Given that all student rosters are different, teachers can create the social markers relevant to their students. For instance, some classrooms may have less economic diversity but greater linguistic diversity. Also, some classrooms may have greater gender diversity, in which case teachers may want to incorporate additional gender categories for students beyond the typical gender binary.

Second, EQUIP is adaptable in terms of "discourse dimensions," which are those qualitative aspects of classroom discourse that teachers think matter for their students' learning. Teachers commonly track the kinds of questions they ask different students and the quality of students' responses. However, teachers might also be interested in more subtle talk and actions, such as students' level of enthusiasm or the presence of microaggressions. Again, teachers decide which discourse dimensions to track and configure EQUIP accordingly.

Our context: Integrating computation into high school physics

To illustrate how teachers can use EQUIP to improve their practice, we describe a project involving high school physics teachers from Michigan. Our team supported partner teachers to develop and implement new computation-based physics activities. This work was partially inspired by the Next Generation Science Standards[17] (NGSS), which recognize "computational thinking" as a key scientific practice. Building lessons on topics ranging from spring oscillation to projectile motion, teachers incorporated opportunities for students to create visual models of physical phenomena using GlowScript, a programming environment for creating simulations. Equity was a key focus of our joint work, since research shows that access to computation in the United States remains inequitable.[18,19] Collectively, we agreed that the project would only succeed if students from marginalized groups also gained access to the computational activities, as opposed to only students from historically dominant groups in science.

Nine physics teachers participated in the project during the 2018-2019 school year. All nine teachers identified as white; six identified as men and three as women. Since the computation-based activities were organized around group work, we video recorded two small groups (i.e., two to four students) per classroom, selected based on parental consent and those that included students from marginalized social marker groups, particularly girls and students of color. Teachers then used EQUIP to analyze the participation patterns.

Teachers used an action research model throughout the project. After video data were collected and analyzed in EQUIP, teachers would meet with a research team member to debrief and reflect on their data. Teachers also shared their reflections with the larger group of teachers and researchers, providing an opportunity to work in community and think about how to change their teaching to make their classrooms more equitable, specifically in terms of providing more opportunities for marginalized students to participate. Teachers conducted this action research cycle several times during the school year.

In the remainder of this article, we present our partner teachers' work with EQUIP in the form of three basic steps for any physics teacher to follow: 1) customizing and using EQUIP for your classroom; 2) interpreting EQUIP data and setting equity goals; and 3) making an action plan. We also discuss some of the questions and issues that came up with teachers, as well as some tips for doing this type of equity work.

Step 1: *Customizing & using EQUIP for your classroom*

To support teachers in thinking about which social markers to track, our team asked: *What kinds of hierarchies exist in your building/district and in your classroom*? We wanted teachers to consider inequity in terms of social markers that were locally relevant. Each teacher decided to track several social markers. As Fig. 2 shows, while race and gender were most common, teachers also tracked less-common markers. For example, one teacher worried that students with more

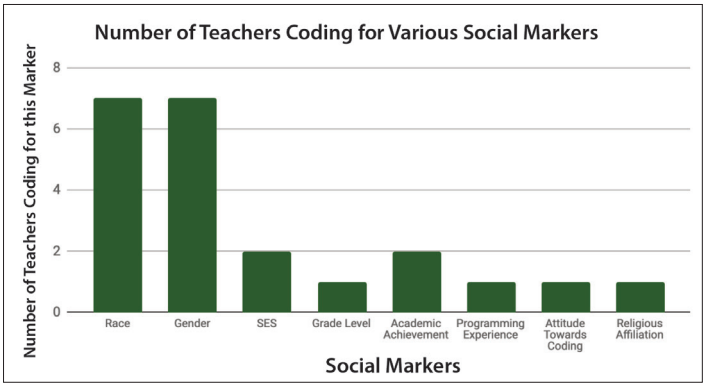

Fig. 2. Social markers tracked by high school physics teachers.

programming experience would be seen as more competent, thereby securing more participation opportunities during the computational activities. Another teacher at an all-girls private school focused on race and SES status, since gender was not relevant in her school context (having no male or nonbinary students in her classes).

With respect to discourse dimensions, most teachers found "content of student talk" (computation/coding; physics; off-topic) and "type of student talk" (question; explanation; other) helpful and informative. Initially, some teachers tracked other discourse dimensions such as "attitude" (positive; negative; neutral) and "participation type" (active; passive). However, the teachers quickly realized that such terms were vague and hard to distinguish and subsequently code based on video. Consequently, teachers did not provide meaningful or actionable data for such vague categories. Another early realization—perhaps out of overzealousness—was that tracking *too many* discourse dimensions at the same time proved impossible. Teachers found that tracking too many dimensions made EQUIP observations complicated and time consuming.

Our research team worked within local school district policies around video recording classroom activities for the purpose of improving professional practice and encourages any teacher hoping to do this work to do the same. With EQUIP customized, teachers then watched their video-recorded classroom sessions while coding for student participation within EQUIP. Some teachers found it useful to do this on two different devices, if available (e.g., watching the video on a computer and using EQUIP on an iPad). In general, teachers reported that they were able to "get the hang of" the EQUIP coding process during their first experience using EQUIP to code their classroom video and that subsequent uses went more quickly and smoothly. In order to reduce the time involved in the coding process, we recommended that teachers use a "time on/time off" approach to watching and coding the video data. For example, a teacher might watch and code for five minutes of video data (i.e., "time on"), then skip the next two minutes of video data (i.e., "time off"), and repeat. However, the "time on" should always be equal to or more than the "time off" so that at least half the video data are both observed and coded using EQUIP. Even with this time-saving suggestion though, most teachers ended up watching and coding the full length of their video data, finding it both interesting and informative.

Tips

- Link the social markers you track to specific inequities happening at your school.
- Identify fewer, less ambiguous discourse dimensions—especially when first using EQUIP.
- To reduce the time requirement, use a "time on/time off" approach to watching and coding video data in EQUIP.

Step 2: *Interpreting EQUIP data and setting equity goals*

EQUIP provides quantitative information on classroom interactions, but the numbers are subject to our interpretations.[20] Therefore, we must think carefully about how and why we interpret in/equity patterns.

To illustrate, consider sample data from a small group of four students: Jalen (Black), Kristy (White), Lequoia (Native), and Monet (Black). Figure 3 shows EQUIP data from two different observations of this group, specifically how explanation-level talk was distributed by race. In both observations, participation is unequal, as Jalen clearly dominated both group sessions. How could these patterns be interpreted?

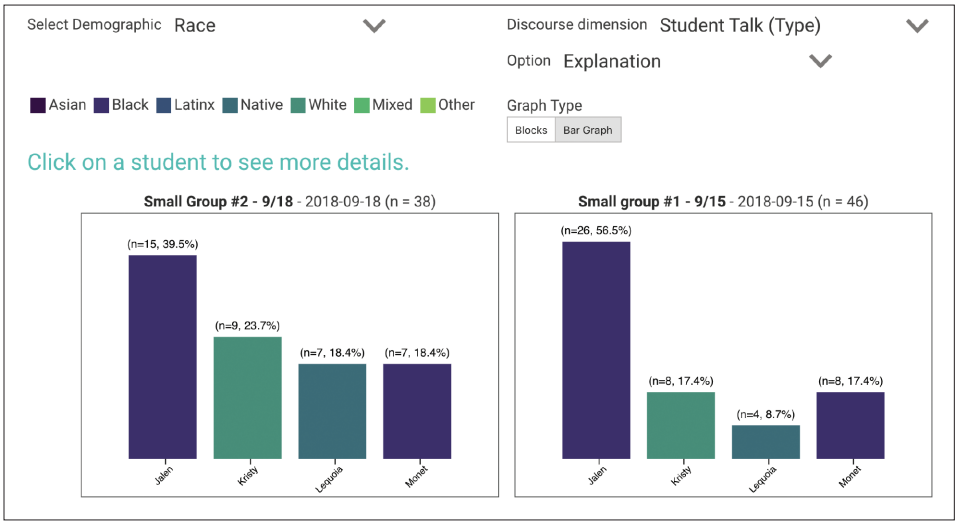

Fig. 3. Sample EQUIP group work analytics.

For some of our partner teachers, these kinds of patterns were problematic. They sought *equality* of participation as a goal: 25% for each student, regardless of students' social markers. However, other teachers found such patterns *equitable*, since the student dominating was a Black young man—a historically marginalized group in science education. From this point of view, quantitative inequality is not considered problematic, but rather can be interpreted as equitable in this case.

The fact that the two girls of color (Lequoia and Monet) participated the least is also noteworthy. Some teachers might interpret this as evidence of individual traits (i.e., shyness or "just a quiet kid") or take a deficit view that they were not as capable as Kristy and Jalen. However, we tried to bring awareness to the influence teachers have on student interactions, through pedagogical structures and classroom norms,[21] even during small group work when students are generally seen as

navigating social interactions more independently. Debriefs with teachers also opened conversations about how racism, sexism, and other oppressive forces might help to interpret the data.

Tips

- When setting equity goals, account for students' social markers and distinguish "equity" from "equality."
- Avoid over-individualized interpretations of EQUIP data; instead, consider the impact of pedagogical structures/norms and social marker-related biases and oppressive forces (e.g., racism, sexism).

Step 3: *Making an action plan*

After interpreting and reflecting on their EQUIP data and classroom video, our partner teachers engaged in collective discussion with each other and with our team about how to address inequities. This involved making an action plan with concrete changes for teachers' classrooms and how they structured group work. We also helped teachers recognize that they have power to influence group work interactions, not just whole-class discussions.

Teachers came up with a number of ways that might attenuate inequity in group work. For example, they discussed assigning specific roles to group members, or physically positioning some students closer to the laptop where they could be less easily ignored by peers. Teachers also grappled with the number of students to put in a group and the number of laptops to give a group, although the availability of technological resources poses its own equity dilemmas.

We do not offer these ideas about group work as "best practices." There are no panaceas to inequity. While our teachers spent time developing their own strategies to enhance group work equity, readers may find it helpful to use existing resources as a launching point for this work, such as STEP-UP materials[22] that offer suggestions for everyday actions teachers can take to support women in physics classrooms (which may be adapted for other marginalized groups) or post-secondary resources, such as R-Cubed[23] from UC Boulder or Minorities in Physics[24] from APS. What matters, though, is the process of generating pedagogical moves and iteratively testing them over time in *your classroom*, as your local context will inevitably shape the way various strategies play out. Our participating teachers kept a running Google Doc where they documented and revised their action plans over multiple iterations of action research. While this can be done individually, we encourage teachers to engage with others to create generative collaborations around collective inquiry.

Tips

- Embrace your power as a teacher to shape equity patterns in your classroom.
- Commit to executing your action plan and revising it over time.
- Engage in the work with others, when possible.

Conclusion

Inequity is an urgent, everyday concern in physics education. All physics teachers can make equity work concrete and actionable by actively monitoring equity patterns in their classrooms. Tools like EQUIP can play a role in this work. We acknowledge that all students should have opportunities to participate in rigorous physics learning, but we caution educators to always reflect on who is prioritized and who is erased when we are not actively attending to students from marginalized groups. When we understand our students and our teaching explicitly in terms of social markers, we stand a better chance of building equitable classrooms for marginalized students.

Acknowledgment

This work was supported in part by NSF Grant No. DRL-1741575.

References

1. A. M. Porter and R. Ivie, *Women in Physics and Astronomy, 2019* (American Institute of Physics, College Park, MD, March 2019).
2. L. Merner and J. Tyler, *African-American Participation Among Bachelors in the Physical Sciences and Engineering* (American Institute of Physics, College Park, MD, Aug. 2019)
3. L. Merner and J. Tyler, *African American, Hispanic, and Native American Women Among Bachelors in Physical Sciences & Engineering* (American Institute of Physics, College Park, MD, Nov. 2017).
4. B. Francis et al., "The construction of physics as a quintessentially masculine subject: Young people's perceptions of gender issues in access to physics," *Sex Roles* **76**, 156–174 (2017).
5. T. Mujtaba and M. Reiss, "Inequality in experiences of physics education: Secondary school girls' and boys' perceptions of their physics education and intentions to continue with physics after the age of 16," *Int. J. Sci. Educ.* **35**, 1824–1845 (2013).
6. S. Fries-Britt, T. K. Younger, and W. D. Hall, "7 lessons from high-achieving students of color in physics," *New Directions Inst. Res.* **148**, 75–83 (2010).
7. J. Rahm and J. C. Moore, "A case study of long-term engagement and identity-in-practice: Insights into the STEM pathways of four underrepresented youths," *J. Res. Sci. Teach.* **53**, 768–801 (2016).
8. K. Rosa and F. M. Mensah, "Educational pathways of Black women physicists: Stories of experiencing and overcoming obstacles in life," *Phys. Rev. Phys. Educ. Res.* **12**, 020113 (2016).
9. D. B. Martin, "Hidden assumptions and unaddressed questions in 'mathematics for all' rhetoric," *Math. Educ.* **13**, 7–21 (2003).
10. R. Gutiérrez, "A 'gap-gazing' fetish in mathematics education? Problematizing research on the achievement gap," *J. Res. Math. Educ.* **39**, 357–364 (2008).
11. D. Reinholz and N. Shah, "Equity analytics: A methodological approach for quantifying participation patterns in mathematics classroom discourse," *J. Res. Math. Educ.* **49**, 140–177 (2018).
12. M. Bang, B. Warren, A. S. Rosebery, and D. Medin, "Desettling expectations in science education," *Hum. Dev.* **55**, 302–318 (2012).
13. N. S. Nasir, *Racialized Identities: Race and Achievement Among African American Youth* (Stanford University Press, Stanford, CA, 2011).

14. National Research Council, *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (National Academy Press, Washington, DC, 2012).
15. B. Van Dusen and J. Nissen, "Equity in college physics student learning: A critical quantitative intersectionality investigation," *J. Res. Sci. Teach.* **57**, 33–57 (2020).
16 American Institute of Physics, "Diversity Statement," https://www.aip.org/diversity-initiatives/diversity-statement .
17. NGSS Lead States, *Next Generation Science Standards: For States, By States* (National Academy Press, Washington, DC, 2013).
18. J. Margolis, *Stuck in the Shallow End: Education, Race, and Computing* (MIT Press, Boston, 2008).
19. N. Shah and C. M. Lewis, "Amplifying and attenuating inequity in collaborative learning: Toward an analytical framework," *Cognit. Instruct.* **37**, 423–452 (2019).
20. D. Gillborn, P. Warmington, and D. Demack, "QuantCrit: Education, policy, 'big data' and principles for a critical race theory of statistics," *Race Ethnicity Educ.* **21**, 158–179 (2018).
21. N. A. Ortiz and T. Davis, "Gladys's lesson plan: A culturally relevant exemplar," *Math. Teach. Learn. Teach. PK-12* **113**, 651–657 (2020).
22. STEP-UP, "Everyday Actions," STEP-UP Physics Together, https://engage.aps.org/stepup/curriculum/everyday , accessed on May 3, 2021.
23. Physics of University of Colorado Boulder, "R-Cubed: Representation, Recruitment, Retention," https://www.colorado.edu/physics/partners/representation-recruitment-and-retention-r-cubed, accessed on May 30, 2021.
24. American Physical Society, "Minorities in Physics," https://www.aps.org/programs/minorities/, accessed on May 17, 2021.

Michigan State University, Department of Teacher Education, East Lansing, MI; jachris@msu.edu