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Negotiating quotidian justice in the science classroom

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ABSTRACT

In this conceptual paper, we explore how science teachers might enact social justice through their everyday science instruction. Drawing on empirical literature and our own K-12 teaching experience, we develop a heuristic for mapping classroom discourses to engage in action and reflection to change both the world of the classroom community, and the world beyond the school. We suggest how this heuristic can be used for justice-oriented science teaching independently of (or as a supplement to) any existing frameworks for science teaching to promote social justice. Our proposed model for social justice through disciplinary science teaching frames justice not as an abstract goal, but as the act of iterating 'quotidian justices' achievable in moment-to-moment pedagogical choices. We contend that this approach allows teachers to resist systemic injustices while also navigating institutional constraints.

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Introduction

It has been over a decade since the National Resource Council (NRC)'s *A Framework for K-12 Science Education* called for changes to support '[science] educational attainment for all students' (NRC, 2012, p. 277). Expressing a similar sentiment more than two decades prior, The American Association for the Advancement of Science (AAAS)'s Project 2061 (AAAS, 1998) proposed education reforms thought necessary to realise a vision of 'science for all Americans.' Whether from the NRC, AAAS, or another source, the call for 'science for all' can feel urgent and fresh, but Barton (2002) traces the lineage of 'science for all' as far back as the middle of the nineteenth century. For nearly 200 years, various forces have called for a high bar of science literacy to be attained by all students. As the notion of who gets to be a student and for what purpose(s) has changed over the past 200 years, the historical record of education in the United States is that the inclusion of students from diverse backgrounds and lived experiences into formal education spaces has resulted in outcomes and opportunities that reflect and intensify systems of racial and gendered domination (Labaree, 2011; Spring, 2016).

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If we really mean to achieve 'science for all' in a literal sense, teachers must attend to each individual student's level of understanding and particular needs. In other words, the call for an outcome of a high-quality science education for every student is a call for equitable science educational practices. Critically, and as in Project 2061 (AAAS, 1998), policy makers, analysts, and researchers may essentially be calling for equity without actually using the term. Rodriguez and Morrison (2019) offer a typology of four common arguments for the importance of greater equity in educational research and practice, which they label as: (a) the economic superiority argument; (b) the moral argument; (c) the demographic shift argument; and (d) the transformative argument. Whether rooted in economic motivations (e.g. AAAS, 1998) or a transformative decolonial critique of science as waging epistemic and physical violence against Black and Brown bodies (e.g. Jones & Melo, 2021), disparate political forces working from a diverse array of philosophical positions have aligned such that advancing more equitable outcomes for the science students in the United States has become a mainstream idea. As Vakil (2018) observes, rather than a liberal agenda, equity in science education has long been a rare bipartisan issue. How, then, can educators enact equitable teaching practices and realise the ideal of 'science for all?'.

The fields of science education and science education research have responded to calls for an increased focus on equity, inclusion, and justice, in part, through education and professional development based on framing discrete sociological concepts (e.g. implicit bias, intersectionality, colourblind racism) (Dewsbury, 2017; Avraamidou, 2020; Goode et al., 2021) as important considerations for planning science instruction. Discrete topics present in professional development for equitable, inclusive, and just science education are typically developed outside of the field of education research. Greenwald and Krieger's (2006) and Crenshaw's (2017) work in the area of legal studies, and Bonilla-Silva's (2013) work in sociology, for example, have served as foundational reference points for educational research guided by considerations of implicit bias, intersectionality, and colourblind racism, respectively. Structurally, the model of professional development to foster equity, inclusion, and justice in science education mentioned above draws from descriptive theories of systems of oppression and operates under the assumption that helping teachers see a more complete picture of a social dynamic will help inform what we ought to (or ought not to) do to resist systems of oppression.

As former K-12 science educators and current science education researchers, we acknowledge the attempts to cultivate broader teacher understandings as a positive step in creating more equitable, inclusive, and just science educational practices. In our professional experience, however, we have wondered why introducing a particular discourse may not always have the intended impact of resisting an oppressive system that hampers achieving science for all. For example, we feel that it is possible to accept Bonilla-Silva's (2013) conceptual framework of colourblind racism as valid and relevant within science education, yet still enact practices that do not provide an equitable experience for students of colour. Through our engagements with secondary science teaching, science education research, and conducting professional development experiences designed for in-service teachers, we find that common frameworks for justice-oriented science teaching based on descriptive theories often fail to provide guidance that enables educators to understand the systemic impact of their disciplinary science teaching practices.

In particular, we are interested in helping teachers to enact praxis – 'reflection and action upon the world to transform it' (Freire, 1970, p. 25). Within the context of

praxis, a key difference between a descriptive theory of systems of oppression and a theory of how to effect change on systems of oppression lies in the question of reflection; namely, upon what might we ask teachers to reflect when they engage in action upon the world to transform it? A systemic perspective gained through engagement with descriptive theory is certainly important and helpful, but perspective alone has limited transformative power if individuals do not control (or do not feel as though they control) systems of power and oppression. We are interested in a theory of praxis that acknowledges systems as an important consideration of reflection, but localises teachers' reflections to the physical and social world of the classroom. In K-12 education today, science educators operate under a variety of constraints (including content standards, pacing guides, and state laws) but still exercise agency in the sequencing of their lessons, the presentation of content within their courses, and – perhaps most importantly – structuring interactions with and among students. Thus, we understand science teachers as already engaged in the praxis of the world of the classroom, and we want to explore the possibilities attendant to connecting teachers to an additional transformational praxis of the world *outside of* the classroom. Put simply, we are interested in supporting everyday science teaching (e.g. properties of inverse square laws, stoichiometry, glycolysis, etc.) that also resists unjust systems at the global scale through praxis at the local (i.e. classroom) scale.

In this conceptual paper, we explore existing empirical literature that appears to describe such simultaneous local and global praxis, as experienced by science educators. Drawing from Calabrese Barton and Tan's (2020) rightful presence framework, we map the classroom practices of science teachers' attempts at praxis to build a theory of how educators might organise their teaching practices to resist unjust systems through student engagement with science lessons (as opposed to a lesson about unjust systems that frames a science lesson, for example). Our resultant model of praxis articulates a mechanism of 'quotidian injustices' (Calabrese Barton & Tan, 2020), thereby relocating justice from an abstracted location that lacks spatial and/or temporal relation to an educator's locus of control. We suggest that, instead of targeting society or systems directly, we may resist systems and enact justice by targeting our own seemingly mundane practices as science educators; through moment-to-moment science teaching discourses, we may make quotidian (i.e., daily) justices through a simultaneous praxis of the world of the classroom and the world beyond the classroom. To that end, we present a justice-oriented heuristic for putting everyday science teaching practices into relation with, and resistance to, exclusionary and unjust systems.

Rationale

Science educators are certainly not alone in their desire to advance equitable outcomes for their students. The field of sociology has mature models which describe the exclusionary systems and power dynamics of race, gender, ethnicity, class, etc., that motivate calls for equity, inclusion, and justice (e.g.; Yuval-Davis, 1997; Hall, 2017; Davis, 1983), and science educators may borrow sociological concepts that are thought to have substantial utility for justice-oriented science teaching. When justice-oriented science educators engage with a sociological concept, they gain the tangible benefit of a vocabulary and interpretative lens in common with other educators and activists. For example, Dewsbury

and Brame (2019) speak to the importance of managing stereotype threat as defined by Steele and Aronson (1995) in order to create inclusive classroom spaces. A science teacher could read Dewsbury and Brame (2019), continue exploring other resources on stereotype threat (e.g. empirical literature, practitioner pieces, colleagues, etc.), and evolve their classroom practices in light of deepened knowledge on the topic. However, borrowed sociological concepts carry a liability associated with their interpretation by individual teachers. For example, in attempting to use 'language that signals an identity-safe environment' (Dewsbury & Brame, 2019, p. 3), a science teacher may fail to understand (or learn) what that might mean in the context of science teaching and learning. We see it as a non-trivial task to implement language that creates both a science pedagogical environment and an identity-safe environment. When science educators make science-pedagogical-meaning (e.g. of their professional experience, that of their colleagues, empirical findings, etc.) through the lens of sociological theories, the act of interpretation leaves students vulnerable to adverse outcomes that may arise from a teacher's limited sociological understanding and implicit biases. This is not merely a hypothetical concern. In their systematic review of the use of Yosso's (2005) assets-based framework in STEM education, for example, Denton et al. (2020) characterise the engagement of STEM educators and researchers with Yosso's concepts as 'limited' and 'focused on shallow interpretations' (p. 572). We believe that it is critically important for science educators to engage with sociological perspectives on the effects of normative educational practices and how students differentially experience education based on aspects of their identities. Thus, we feel it is important that teachers' work with their students generates feedback about the degree to which their meaning-making with sociological theories may be unproductively limited or shallow.

Individuals who possess relevant sociological and science pedagogical expertise have acted as interlocutors in the past, yielding a supplementary approach to integrating sociological concepts into science pedagogical practice. For example, the Culturally Relevant Science Teaching (CRST) framework articulated by Hernandez et al. (2013) is a critical assessment of science teaching through the lens of culturally relevant pedagogy (CRP) (Ladson-Billings, 1995). As in CRP, CRST identifies the development of students' socio-political consciousnesses as an indicator of culturally relevant [science] teaching. However, in their observations of 12 teacher candidates throughout a multi-year teacher preparation program, Hernandez et al. (2013) found that the candidates' science instruction did not promote the development of their students' socio-political consciousnesses. Hernandez et al. (2013) highlight the difficulty in discerning the significance of the lack of evidence for the development of student socio-political consciousness, an element that is integral to both CRP and CRST. The authors suggest that perhaps social justice was 'not adequately modelled in our teacher preparation program' (p. 817), but they also wonder if the power dynamics associated with beginning teachers working in a political climate that was unsympathetic to social change may have had a silencing effect on the justice-orientation of the teacher candidates.

The study conducted by Hernandez et al. (2013) suggests that – even when researchers support individual pre-service teachers in multi-year engagement with sociological concepts that have been localised by experts to a science pedagogical context – attempts to enact justice-oriented science education may still raise questions of superficiality and shallow understanding. Troublingly, shallow and superficial understandings may be

indistinguishable from structural barriers that would prevent even deeply knowledgeable teachers from enacting justice-oriented science education. The lack of a clear way to discern between a need for greater individual skill, rather than a need for systemic change, complicates the task of using the work by Hernandez et al. (2013) to build individual teachers' capacities in the area of developing students' socio-political consciousnesses. Moreover, building teachers' capacities in this area may prove to be unnecessary in order to meet the authors' stated aim of developing a framework for 'effective [science] teaching for [culturally and linguistically diverse] students' (Hernandez et al., 2013, p. 809). That is, it is not clear whether any perceived shortcomings of CRST as complete instantiations CRP necessarily mean that the teachers did not resist unjust systems. Just because CRST (or any other science teaching) is not exactly CRP does not mean that it is unjust.

Quotidian justice, as enacted in science classrooms

We wish to support science educators in the challenge of adapting diverse sociocultural perspectives of justice to the context of the science classroom, specifically by 'making present the lives of those made missing by the systemic injustices inherent in schooling and the disciplines' (Calabrese Barton & Tan, 2020, p. 436). In this paper, we engage with some of the empirical literature on justice-oriented science education to develop a model of everyday science teaching that may also be understood as praxis. Such praxis entails interrogating the degree to which our attempts to teach with a justice orientation 'further the very relations we seek to disrupt' (Kuntz, 2022, p. 595) both inside and outside of the classroom. To discern the connections among particular science pedagogical practices and systems of power and oppression, we explore empirical literature from the fields of science and STEM education in order to map 'particular entry points of resistance that short-circuit the full articulation' (Kuntz, 2022, p. 595) of unjust systems. Because we are interested in developing models for what teachers might do in order to engage students in science learning that resists unjust systems, we do not present (nor did we attempt) a scoping review of social justice as achieved via science teaching practices. Rather, we attempted to find concrete examples of empirical literature where the researchers described high quality student learning of science content (e.g. physics, chemistry, biology, etc.) that also had the effect of resisting particular injustices. We wanted to understand how the justices attendant to everyday science teaching might have been working at a structural level, such that the enacted justices in the literature could be tried as a model in different educational contexts.

Methods

Participation mapping within the science classroom

Drawing from Kuntz's writings on critical cartography, we begin with the supposition that teachers cannot disrupt unjust systems 'without knowing what these things are, how they manifest, and the effects they generate' (Kuntz, 2022, p. 597). Kuntz (2022) is silent on the question of the specific actions we might undertake to articulate our collective participation in unjust systems through disciplinary science education. Thankfully, Maton and Howard (2018) defined a 2-D Cartesian 'autonomy plane' that served

to map classroom practices that either support insulated, autonomous knowledge or subvert such systems. Crucially for our work, they also articulated the concept of 'autonomy pathways' that map how an educator might move about this plane over time (Maton & Howard, 2018). Adendorff and Blackie (2020) used the autonomy plane and pathways to map a complex tension between science curricula and decolonial activism in South Africa. As we reflected on their alignment of various South African science curricula to this map, we recognised the potential of this approach in mapping the classroom practices that cultivate the rightful presence and quotidian justice that Calabrese Barton and Tan (2019) describe. We therefore created a similar 2-D plane to facilitate mapping science educational and social processes within the science classroom. In the following section, we present the Participation Map as a tool that can serve as a heuristic for waging resistance against exclusionary and unjust systems.

The participation map

We will use a participation map (shown with the quadrants labelled in Figure 1) to document the source and purpose of classroom discourses. Recalling the rightful presence perspective of Calabrese Barton and Tan (2020), the 'participation' of teachers and their students in systems is represented by how classroom activities move around the participation map over time, either conforming to established modes of power and authority or challenging them. The y-axis of the participation map indicates the degree to which the content of a classroom discourse and/or activity resides within what is canonically considered to be 'science curriculum.' The x-axis of the participation map indicates the degree to which a classroom discourse and/or activity has been invoked for the purposes of learning science curricular content (as defined above).

To clarify the participation map, Figure 2 illustrates the discourses present in a hypothetical science class in which a teacher greets her students, takes attendance, reviews the answers to the prior evening's homework assignment, and then has the students conduct a confirmatory laboratory activity (e.g. measuring g, the acceleration due to Earth's gravitation).

Although they are important activities, greeting students and taking attendance are not generally considered to be science-specific practices, nor are they undertaken for

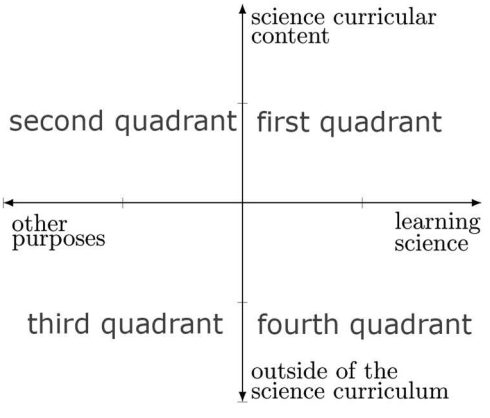

Figure 1. A participation map.

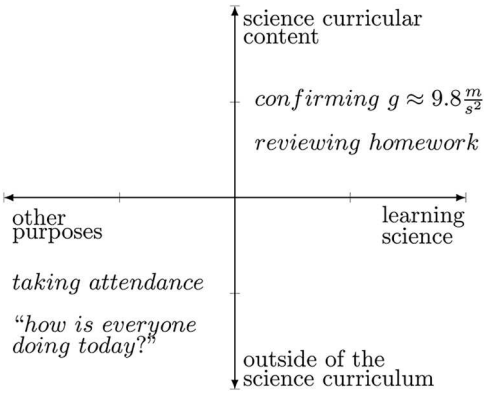

Figure 2. A hypothetical science class period illustrated on a participation map.

the purposes of learning science-specific content. Thus, these activities are located within the third quadrant of the participation map (i.e. not canonical science content, and not introduced for the purpose of learning science). Alternatively, correcting homework and engaging in confirmatory laboratory activities are undertaken for the purposes of learning science content and engaging in scientific practices, and these activities are therefore located in the first quadrant of the participation map.

Mapping and discernment of science pedagogical justice

To build a theory of how educators might organise their teaching practices to resist unjust systems through student engagement in science lessons, we use a participation map to characterise accounts of science educational practices. Creating participation maps from narrated accounts of teaching will help us to explore the question of how a systems perspective and a personal commitment to the ideals of inclusion and justice sometimes lead to practical effects that intensify unjust systems. The classroom dynamics described in examples of justice-oriented teaching from the empirical literature are framed as successful examples of teachers' simultaneous praxis of the classroom and the world outside of the classroom. We will also use the participation map to analyse two examples of justice-oriented teaching from the first author's 20-year career teaching secondary science: one in which a social justice motivation reinforced an unjust system outside the classroom, and one that further marginalised students. Taken from different teaching contexts and superficially different in scope and form, these inputs will be used as the basis for an inductive model of justice, as enacted via science pedagogical practices.

Results

Example 1: 'The Occupied' (Calabrese Barton & Tan, 2019)

Calabrese Barton and Tan (2019) advance the concept of rightful presence when considering actions that disrupt unjust systems and ways of knowing in the classroom. They define rightful presence as:

> legitimate membership in a classroom community because of who one is (not who one should be), in which the practices of that community work toward and support restructuring power dynamics toward more just ends through making injustice and social change visible (p. 619).

Calabrese Barton and Tan (2019) illustrate an instantiation of rightful presence through 'The Occupied,' an example of justice-oriented teaching in which a middle school science teacher, Ms. J., connected science disciplinary knowledge to students' cultures and social justice. Critically, The Occupied explores teaching that explicitly disrupts quotidian injustices – the exclusionary and unjust systems of power that are routinely manifested in classroom practices – and brings students into rightful presence.

The Occupied is the result of a project in which middle school students were asked to use a renewable energy source to address a classroom community concern. The students identified bathroom bullying (a common practice of barging in on students in the bathroom and spreading rumours about the student using the facilities) as an important concern. The students had reported the issue to school authorities but felt like nothing was improving because the students who barged in on others in the bathroom could plausibly claim they did not know the facilities were occupied. After the act of pretending to be unaware that the classroom bathroom was unoccupied was identified as a critical point for disrupting bullying, the students built The Occupied, an LED array outside of the bathroom that indicates whether the bathroom is occupied. Powered by a photovoltaic cell inside of the bathroom, The Occupied is actuated by the bathroom light, eliminating any ambiguity as to whether or not the bathroom is available. Calabrese Barton and Tan (2020) detail how The Occupied engaged students in 'high-quality STEM learning' (p. 437) that improved the material conditions of 'a political struggle for most boys of colour in [the] class' (p. 437). Figure 3 shows the participation map associated with The Occupied classroom activities. The project began with students identifying a community concern for the purposes of improving the classroom community (third quadrant). Students then learned about renewable energy in the context of their community problem in order to imagine solutions (fourth quadrant). In order to actually build The Occupied, students needed to learn about the design and construction of electric circuits (first quadrant). Finally, the students

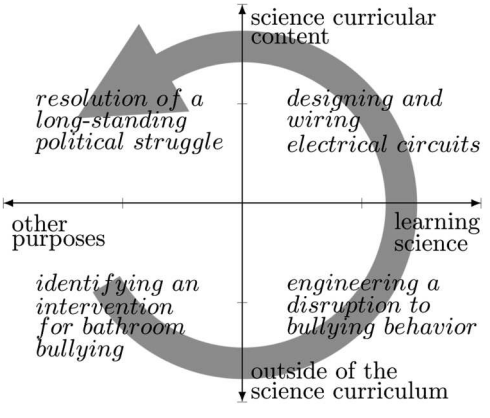

Figure 3. "The Occupied" (Calabrese Barton & Tan, 2019) illustrated on a participation map.

applied their first-quadrant science learning to the construction of The Occupied, in order to address the problem of bathroom bullying (second quadrant).

The transformative potential of The Occupied was realised when the students' teacher, Ms. J, made time and space for the class to 'figure out how your project really works in real life' (Calabrese Barton & Tan, 2019, p. 648). The authors detail how, initially, Ms. J needed to be convinced that bathroom bullying was 'a problem worth solving in a STEM classroom' (p. 617). Ms. J.'s work with the researchers to bring students into rightful presence, resulted in transformative effects which were not limited to Ms. J.'s students. The experience surfaced and combatted Ms. J.'s implicit biases about her students' capabilities, and tangibly revealed how Ms. J.'s limited understanding of her students' capacity to engage in a socio-transformative engineering project was a longstanding quotidian injustice. In terms of the participation map, the second quadrant is the location of important classroom discourses that resist unjust systems. The experience of The Occupied was one in which the science curricular content of parallel circuits, conductors, and renewable energy sources were used for the purposes of reconfiguring the social relations of the classroom.

Example 2: an antiracist justice-oriented college biochemistry course (Hollond et al., 2022)

Hollond et al. (2022) describe the design and implementation of an antiracist undergraduate biochemistry course that ''explicitly addressed racism, social justice, and equity and directly integrated these ideas in the science curriculum' (p. 202). In contrast to Calabrese Barton and Tan's (2019) conception of justice within the classroom, Hollond et al. operationalise justice in terms of power, privilege, and social identities, as experienced in the world outside of the classroom. Hollond et al. had students engage with the theme 'Racism is a Public Health Emergency' to 'consider specific actions to eliminate injustice and create more equitable outcomes in biochemistry and related fields' (p. 204). Students learned about implicit bias and systemic racism, and then used these concepts to engage in the critical examination of biochemistry topics in society (e.g. how racist systems are manifested in the practice of medicine). After grounding the textbook biochemistry curricular content in systems of power and oppression, students attained deepened biochemical and social justice perspectives. Compared to previous non-justice-oriented iterations of the course, Hollond et al. reported increased learning of the science material and student motivation to use their new understandings of the role of racism in science and medicine to improve society. Figure 4 shows the participation map of a particular unit of study described by Hollond et al. (2022). Similar to Figure 3, the arc of the justice-oriented biochemistry course begins in the third quadrant, this time through introduction of implicit bias and systemic racism as grounding concepts for the microbiology curricular topics. The classroom discourse then transitioned into a discussion of sugar in human diets and a systemic approach to understanding its inequitable health effects on minoritized populations (fourth quadrant). From a broader cultural context, students were asked to use diabetes as a foil to synthesise the biochemistry curricular topics studied throughout the semester (first quadrant). Finally, students were asked to re-engage with the same topics for the purposes of identifying 'specific actions to eliminate injustice and create more equitable outcomes' (p. 204) (the second quadrant).

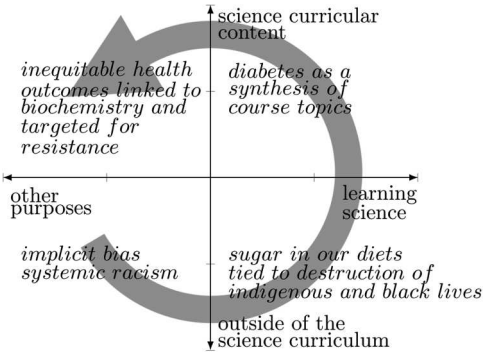

Figure 4. A justice-oriented biochemistry unit (Hollond et al., 2022) illustrated on a participation map.

As in The Occupied (Calabrese Barton & Tan, 2019), Hollond et al. (2022) point to student engagements that we plot in the second quadrant of the participation map as evidence that the transformative potential of their antiracist biochemistry course was actually realised. Ultimately, the biochemistry course resisted exclusionary and unjust systems by holding students accountable to the task of transforming biochemistry from an abstraction present in a textbook, to a field that 'exacerbates social/racial inequality' (p. 208), then identifying 'things we can do to change that' (p. 208). In other words, justice was enacted in a transition from the first quadrant to the second quadrant that was characterised by student agency to bring science understandings into resistance to unjust systems of power and oppression.

Working in different educational contexts, and with different operationalizations of justice, both The Occupied (Calabrese Barton & Tan, 2020) and the biochemistry course designed by Hollond et al. (2022) enacted justice-oriented teaching using an identical structure on the participation map; both enactments began in the third quadrant and negotiated a counterclockwise loop through adjacent quadrants on the participation map. To better understand the features that suggest justice within a participation map, we will examine two additional types of justice-oriented teaching. Both types of enactments shared the motivations, socio-cultural contextualisation, and critical perspectives evident in Calabrese Barton and Tan (2019) and Hollond et al. (2022), yet these enactments *perpetuated* unjust systems. These counterexamples will help pinpoint whether it is the counterclockwise circulation itself, or a particular feature of the participation map (e.g. any circle, a visit to the third quadrant, etc.) that may effect justice.

Example 3: accidental injustice in a high school chemistry course

(The example below relates the experiences and analysis of the first author and is written in the first person in order to more directly relate the first author's perspective on enacting justice in a high school science classroom.)

In my final year of teaching high school chemistry, positing that high stakes testing practices were an unjust detriment to the mental health of our students, the school leadership asked all teachers to consider ways in which traditional testing might be eliminated from their courses. As a member of the school's leadership team for diversity, equity, inclusion, and justice, I attempted to model an implementation of our 9th

grade science course that eliminated testing. Instead of single-attempt quizzes and tests, I allowed my students unlimited attempts to demonstrate their understanding via a series of dialogic video assessments. For each unit, I articulated the specific competencies to be demonstrated, and let my students decide what should be included in the video that would constitute evidence of their understanding. I was pleased to find that my students were able to demonstrate a deep understanding of the chemistry content and sophisticated problem-solving skills under the new assessment scheme. Although the new assessment strategy was successful from my perspective, I later learned that my students had mixed feelings.

Figure 5 illustrates a particular unit in the chemistry course, articulated onto the participation map. Students began by learning about orbitals and electron configurations (first quadrant), and then were asked to create a physical model of the atom with household items that reflected their understanding of orbitals (fourth quadrant). The students made a video demonstrating the use of their atomic models to predict the electron configurations of an element, based on its number of electrons. This activity engaged students in video recording and editing (not science curricular content) for the purposes of demonstrating their physical model (which was created in addition to activities within the established curriculum) and is thus a third-quadrant activity. If I deemed it necessary, students engaged in a series of additional back-and-forth videos with me to adapt and refine their model to create additional explanatory power (second quadrant).

While many students initially expressed a sentiment that the video assessments were engaging and a welcome opportunity for creativity, they eventually began to object that it did not feel fair to spend several hours making videos when their peers in another class might only spend 30 min studying for a test. The impact of my assessment strategy was in palpable opposition to my intent to teach a justice-oriented course in support of students' well-being. Time spent filming and editing video beyond the 30 min their peers might spend on assessments was time my students no longer had to connect with family, be active, catch up on much-needed sleep, or pursue their own notions of justice.

Reflecting on the experience, I now understand the failure to achieve a justice orientation as rooted in teaching to enact my own (and the school leadership's) sense of what justice should mean for my students. Operating under the mistaken

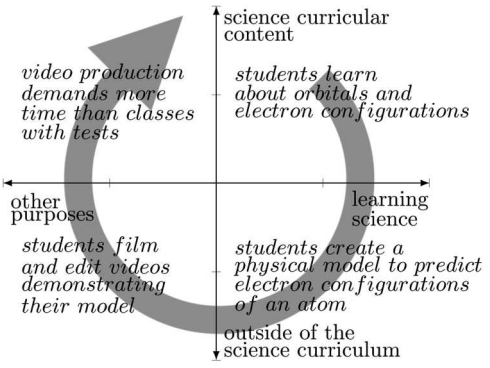

Figure 5. A novel assessment strategy that failed to realise a justice orientation.

impression that eliminating testing was inherently enacting justice, rather than locating 'particular entry points of resistance that short-circuit the full articulation of fascist force' (Kuntz, 2022, p. 595), I inadvertently enacted a new articulation of fascist force in the school community. I was so focused on a praxis of the world outside of the classroom (i.e. disrupting the negative effects of high stakes testing on students, in a general sense) that I lost sight of the praxis of the classroom (and my particular students). My official roles as chemistry teacher, department chair, and DEI leader within the school contributed to a power dynamic that made it difficult to get honest feedback about the impact of my efforts in real time, and I failed to create another mechanism to gauge the effects of my justice-orientation beyond student feedback and their performance on assessments.

Example 4: student hostility toward justice-oriented teaching

(Similar to the previous example, the example below relates the experiences and analysis of the first author and is written in the first person in order to more directly relate the first author's perspective on enacting justice in a high school science classroom.)

As a biology teacher, I would spotlight Rosalind Franklin's contributions to the discovery of the structure of DNA and engage students in the ethical considerations of the appropriation of her intellectual property and erasure from popular science history. At some point, however, what was received as the history portion of the unit would end and students would learn what they perceived to be the actual course content (e.g. nucleotide structure, base pairing rules, etc.). In both my own teaching and observations of my colleagues, I have seen many attempts to promote equity, inclusion, and justice through classroom discourses that unfold in the same way: an important (to the teacher, at least) historical event or sociopolitical context that does not receive emphasis in the textbook, followed by a return to the canonical textbook content. This type of teaching is congruent with the level one 'contributions approach' to multicultural curriculum reform (Banks, 1993). Figure 6 illustrates the participation maps of the contributions approach, generally, as well as the specific example of Rosalind Franklin.

In contrast to the examples of justice-oriented teaching from Calabrese Barton and Tan (2020) and Hollond et al. (2022), the examples of classroom discourses of the form shown in Figure 6 are prone to leaving students wondering 'what does this have to do with science?' (or, worse, presuming that there is no relation). What, then, are the effects of social justice topics that are not understood as integral to the science curriculum? In my experience, the outcome was antithetical to the desired effect of introducing counternarratives and silenced histories. In some students, the sociocultural context to science lessons strengthened a false dichotomy between subjective social issues and science as something objective. Even students who found the additional context interesting and meaningful did not always desire a sociocultural grounding in their science lessons. Many students' understandings of the appropriate use of class time were limited to preparation for assessments and future science classes. For these students, discourses in the third quadrant of the participation map were perceived as unnecessary for learning science curricular content, and an unwanted instance of being told what and how to think.

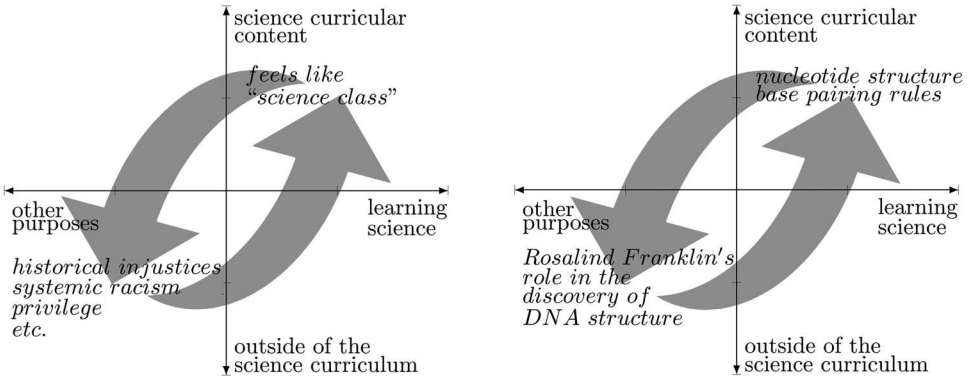

Figure 6. An attempted justice orientation conceived as a "contributions approach" (Banks, 1993).

Discussion

A theory of justice, as enacted via science pedagogical practices

Through selections from empirical literature and professional experiences, we have articulated three distinct forms of teaching that were thought to promote justice. When plotted on a participation map, their pathways take the form of (a) counterclockwise loops; (b) clockwise loops; and (c) oscillations between the first and third quadrant. Of these, we understand counterclockwise loops as having resisted unjust systems in two distinct science educational settings ('The Occupied' and an anti-racist biochemistry course), while the clockwise loop and oscillation between the first and third quadrant employed social justice framings and language, but did not resist unjust systems. Thus, we postulate that the counterclockwise loop is the most effective pathway for science educators to resist exclusionary and unjust systems. Drawing from Kuntz's (2022) cartographic methodology, we hypothesise that justice, as enacted via science pedagogy, comprises four actions which may be discerned on the participation map, as shown in Figure 7: engaging students' cultures, integrating students' cultures into science classroom culture, supporting individual students' science learning, and supporting students to reauthor their rights and roles within science education.

The importance of the student agency in second-quadrant discourses

Contrasting the specific examples of the praxis described by Calabrese Barton and Tan (2020) and Hollond et al. (2022) and the example of supposedly-just video assessments in a chemistry class, it is clear that not all activities that would be plotted in the second quadrant of the participation map put the effects of teaching into a justice orientation. Rather, the second quadrant is the site in which exclusionary and unjust systems may (or may not) be contested. Thus, whether or not a lesson that involves social justice topics is actually an example of praxis hinges on whether students are supported in bringing their resistive science agencies to bear on unjust systems. The unsuccessful examples of justice-oriented teaching described above may thoroughly ground disciplinary ideas in sociological contexts, but they maintained students within the traditional power dynamic of the class and did not create opportunities for collective

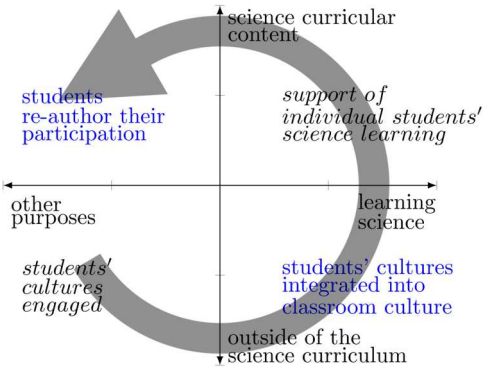

Figure 7. Four actions of enacting quotidian justices via disciplinary science teaching.

disruption of guest/host classroom relationalities (Calabrese Barton & Tan, 2020). Justice-oriented teaching that does not support students as agents of resistive social change masquerades as transformative (e.g. invokes the language of social change), but merely articulates new ways to accommodate calls for change without interrogating the presumption that the existing curricular aims are compatible with justice. We see the second quadrant, then, as an inflection point at which exclusionary and unjust systems are either resisted or reinforced, based largely on how students are invited to participate in their science education.

A heuristic for teaching science and making justice

We contend that, in the absence of a magic wand, justice is a necessarily iterative endeavour. The model of justice illustrated in Figure 7 maps and discerns justice as a complete counterclockwise circulation on the participation map. If we are to keep circulating in the name of iterative justice, however, it is not clear why justice must always begin in the third quadrant of the participation map. On the contrary, Kuntz (2022) reminds us that everything is a potential entry point into resisting unjust systems. Thus, we invoke Maton and Howard's (2018) 'autonomy pathways' in suggesting that it is the trajectory through the participation map (i.e. the unfolding process of practices and student engagements), and not the starting point (i.e. the third quadrant) that is helpful in understanding the relationships between science teaching and unjust systems. We postulate that any starting point (whether it is students' CCW (Yosso, 2005) or the specific page number in a district pacing guide) may serve as a basis for integrative knowledge-building that embodies a justice-orientation toward both science education and resistive participation in unjust systems. With the final addition of an iterative path toward justice, Figure 8 articulates the product of this analysis: a heuristic for putting everyday science teaching practices into relation with, and resistance to, exclusionary and unjust systems.

Acknowledging teachers' competing priorities

Any useful heuristic for justice-oriented science teaching must acknowledge the conflicted professional experiences and finite temporal and material resources of teachers. To have any utility, the model of justice articulated here must be congruent with the

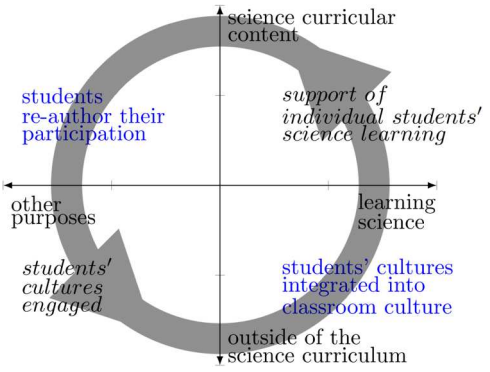

Figure 8. A heuristic for negotiating quotidian justices.

reality that there are committed, justice-oriented educators who – in a particular moment – feel an urgent need to do something other than the most-possibly-just thing. Moreover, a heuristic built on the model in Figure 7 must support educators in undertaking less-just practices (e.g. giving a test at the end of a grading period, or grading their students at all, for that matter) without interpreting these practices as a lack of commitment to justice. The heuristic developed above frames any educator who understands their justice-orientation using the model of justice (shown in the participation map in Figure 7) as 'keeping vigil with the hope of reordering contemporary limits' (Kuntz, 2022, p. 611). Even if it is not undertaken to resist unjust systems, when a possible means of reordering contemporary limits is identified, the act of imagining has surfaced and made present invisible quotidian reflexes that support unjust systems. The tension between what a justice-oriented teacher may want to do and what a teacher feels they must do manifests the political struggle at the core of many frameworks for justice (including Calabrese Barton & Tan, 2020). Here, we are reminded of decolonial scholar Boaventura de Sousa Santos's caution that 'commitment must be distinguished from militancy' (Santos, 2018, p. 277). We contend that engaging with this tension is not an act of less-than-justice. Rather, a critical agency is to articulate and navigate to those limits only sensed through tension so that we may engage in their reordering.

After striving to discern quotidian injustices (Calabrese Barton & Tan, 2020) and map ways to make quotidian justices, our justice-oriented prescriptions offered here are not particularly exotic. On the contrary, these same discourses have existed for at least a few decades in the reformed science teaching literature. The reformed teaching observation protocol (RTOP) (Sawada et al., 2002), for example, contains several items that suggest the same set of discourses derived from our attempt to describe a heuristic for justice-oriented science teaching. In particular, the RTOP items that emphasise (a) 'connections with … real world phenomena;' (b) student reflection about their learning; (c) 'constructive criticism, and the challenging of ideas;' and (d) 'a high proportion of student talk' (p. 253) would be evidenced by students engaging a resistive science agency in the second quadrant. Moreover, the disruption to the guest/host relations (Calabrese Barton & Tan, 2020) itself orients toward greater justice, obviating the necessity for the production of a tangible product (e.g. The Occupied) as a requisite for justice. In short, we believe that teachers may be able to orient their teaching toward negotiating

quotidian justices without needing to add an additional teaching philosophy and accompanying suite of science pedagogical practices. Again, we are interested in everyday science teaching (e.g. properties of inverse square laws, stoichiometry, glycolysis, etc.) that also resists the full articulation of unjust systems.

Implications for research and practice

Our aims in writing this conceptual paper were to (1) understand how theories meant to describe material conditions of injustice are not always effective as a means to resist unjust systems through science teaching; and (2) provide a practical tool for science teacher praxis. By mapping the practices of educators who connected their disciplinary teaching practices to social justice, we created a model of how justice might be enacted through everyday science teaching. To generate a heuristic from this particular conception of justice, we oriented Calabrese Barton and Tan's (2020) rightful presence framework toward a rightful *present* – a site for resisting and disrupting exclusionary and unjust systems that is always reachable, moment-to-moment, in every science classroom.

We postulate that engagement with the rightful present engages teachers and students in an intentional set of moment-to-moment choices that are simultaneously mundane yet powerful: what students are doing, what problems are the focus of the classroom community, and the collective purpose of the teacher and students. The resulting heuristic for negotiating quotidian justices is offered for use independent of explicit connections to sociological theories, but it is also congruent with existing theories of justice-oriented education (e.g. CRP and CRST), as well as reformed science teaching practices. It is our hope that the preceding theoretical engagement with – and analysis of – enactments of justice-oriented teaching support the following prescription: as a heuristic for everyday science teaching practices that surface and resist exclusionary and unjust systems, use Figure 8 to locate the current (i.e. in the immediate present) classroom discourse on the participation map and engage the classroom community in imagining ways to enact multiple counterclockwise circulations. If the counterclockwise movement slows, or even reverses, that is evidence of a surfacing articulation of systems of power and oppression (and not evidence of a lack of a commitment to justice). Justice is enacted in discerning and mapping injustice (Kuntz, 2022), as well as the parts that feel more overtly like making. Try to keep circulating counterclockwise.

Implications for science teaching practice

When justice is discerned as comprising a sequence of four discourses: (a) engaging students' cultures; (b) integrating students' cultures into science classroom culture; (c) supporting individual students' science learning; and (d) supporting students to reauthor their rights and participation within science education, it is not difficult to imagine congruent types of everyday science teaching. With the addition of an appropriate second quadrant activity (i.e. one that engages students as agents of resistive social change), a mundane example of chemistry teaching can be harmonised with the structure of justice-oriented teaching. What quotidian science classroom discourses might empower students to resist unjust systems via their science agency? We see one opportunity for justice-oriented engagement with the present when the portion of a lesson or

unit in the first quadrant (i.e. topics from the external science curriculum, invoked for the purpose of students learning disciplinary science skills and knowledge) concludes.

Rather than signifying an endpoint, completed first quadrant disciplinary study might be more appropriately understood as continuing – in some fashion – into the second quadrant. An immediate transition to the next curricular topic (though it may begin with sociological contextualisation) invokes science curricular content for purposes other than the science learning in which students are already currently engaged. Changing topics to maintain the pace of a course is a second quadrant activity that maintains and sustains current systems by positioning students as passengers rather than drivers of their education. Calabrese Barton and Tan (2020) call for 'making present the intersections of contemporary (in)justices, while orienting towards new, just social futures' (p. 436). Specifically, they suggest a 'collective disruption of guest/host classroom relationalities' (p. 437) as a specific tenet of rightful presence. Another tenet of rightful presence calls for 'teaching and learning alongside amplifications of youth's lives and wisdom, such that new possibilities for social change arise' (p. 436). From these tenets, we may consider that entering into second quadrant systemic resistance may be as simple as asking students what else they know or wonder about the topic, and/or what they imagine could be done with their newly constructed knowledges. In other words, when a first quadrant discourse concludes, a democratising move to understand where students can imagine going next is a second quadrant activity that is consistent with rightful presence (Calabrese Barton & Tan, 2020) and our empirically-driven inductive heuristic for justice presented in Figure 8. To further supplement the heuristic in Figure 8, we offer the following quadrant transition strategies to engage students and move counterclockwise through a participation map:

- 'What is a need we might meet with [some skill or knowledge]?' Can move the lesson from the first quadrant to the second quadrant.
- 'Why is that important to you?' Can move the lesson from the second quadrant to the third quadrant.
- 'What does the rest of the classroom community need to know to bring our science skills to bear on that need?' Can move the lesson from the third quadrant to the fourth quadrant.
- 'What science skills and knowledge would help the classroom community meet that need?' Can move the lesson from the fourth quadrant to the first quadrant.

We offer these solely as concrete suggestions, and not prescriptions. Of course, we are hopeful that teachers will take notice of what organic classroom interactions transition the class to adjacent quadrants, and begin to use such experiences as an intentional means of navigating counterclockwise through participation maps. Such action would be the very double praxis of the classroom and the world outside of the class we have sought to facilitate through this analysis.

Implications for research and policy

The primary implication of this analysis for researchers is a heuristic for ordering everyday science pedagogical practices to affect praxis – 'reflection and action upon the world to transform it' (Freire, 1970, p. 25). The heuristic relies on a model of justice that was

developed from empirical literature on justice-oriented science classroom practices (Figure 7). We feel that the model may prove to be useful in other teaching and research contexts. Whether or not the particular articulation of justice in this paper resonates with the reader, we offer the participation map, more generally, as a useful tool for communicating the relationship between science teaching and justice. An implication for researchers is the possibility of using participation maps as the basis for a common reference tool to describe science teaching enactments of justice. Using the participation map in this fashion has led us to wonder about its utility for understanding the integration of other types of discourses into science teaching (e.g. technology, engineering, and maths, to turn science into STEM, arts, to turn STEM into STEAM, etc.). Finally, irrespective of both the specific heuristic for negotiating a quotidian scale of justice, and the model of justice itself, we have attempted to make a tool that may guide science educators in understanding how to enact justice from any classroom starting point: chance interactions with students or Chapter 8 in the textbook, in addition to a cultivated awareness of their funds of knowledge, community cultural wealth, etc.

While some teaching contexts are susceptible to injustices stemming from unavoidable actions that must be undertaken (e.g. taking time to prepare for standardised testing), another type of injustice is enacted by governing what actions must not be taken. On its face, the growing trend of 'anti-woke' school, local, and state governance (e.g. prohibitions against discussing privilege, white supremacy, critical race theory, etc.) threatens to imperil justice-oriented teaching. As shown above, however, the model of science teaching for justice presented here is also reformed science teaching (Sawada et al., 2002). Calabrese Barton and Tan (2020) describe The Occupied as an example of rightful presence, the tenets of which are allied political struggle, making injustice visible, and amplifying the sociopolitical through collective disruption. The Occupied could also accurately be described purely in reformed science teaching (or any other) terms: engaging students as members of a learning community, promoting student exploration, teaching fundamental concepts of a subject, and connecting science to real world phenomena. We contend that it is the tangible reordering of the material conditions and social dynamics of the classroom – and not the vocabulary used with students (nor the vocabulary used by researchers to describe a lesson) – that drives resistance and justice. Thus, if our heuristic does in fact enact justice via science pedagogical practices, teachers do not need to advertise themselves as subverting authority in order to do so.

Conclusions

Although the aim of this article was to engage with empirical literature and our professional experiences to support teachers in enacting science teaching praxis, thinking and writing through that problem necessitated a particular operationalisation of justice. Translocating justice from an abstract location outside of the time and space of everyday science teaching and orienting toward a rightful present yielded several ancillary implications for practice. While some of the implications for practice were anticipated (e.g. the participation map as the basis for a common language and framework to analyse the relationship between classroom practices and systems of power and oppression), others were unexpected (e.g. the degree of harmony between the heuristic

and reformed science teaching practices). To that end, we suggest that any inquiry into science teaching to promote equity, inclusion, and justice will benefit from particularising the science pedagogical meanings of those ideas. Particularisation is more than merely a nice thing to have, however. Instantiations of justice-oriented teaching (e.g. the test-less chemistry class described in this article) based on presumed meanings of causes, problems, and solutions run the risk of strengthening unjust systems in subtle ways that complicate future resistance. To conclude with a more positive corollary to a dire warning, we hope this analysis may also serve to demonstrate the relative ease with which new territories for resistance may be articulated. Perhaps the very ways of teaching for justice, themselves, will be found to be surprisingly diverse, equitable, and inclusive of all teachers and teaching contexts.

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Ethics statement

The primary data for this paper were collected from extant literature and required no ethical approval.

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