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Lessons from a professional learning community: Navigating tensions while moving between theory and practice in teaching chemistry for social justice

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Abstract

Maintaining a commitment to social justice teaching can be especially challenging when navigating the bureaucratic systems and ever-spiraling responsibilities of the education system. To better understand how social-justice-oriented educators navigate these tensions, this paper uses qualitative methods to investigate the social justice problems of practice identified by five chemistry teachers in a year-long professional learning community. By analyzing the challenges described in their problem-posing segments, I identify seven major themes that represent key sources of tension and possibility as teachers move from theory to practice in teaching chemistry for social justice. These findings indicate that the practical considerations of day-to-day teaching practice create the most salient tensions when moving from theoretical ideas of social justice to a deeply integrated enactment of social justice teaching. Through a deeper analysis of two cases, I demonstrate the effects of discussing problems of practice with a group of teachers who had similar disciplinary backgrounds and ideological stances. These discussions shifted the tensions from potential barriers to areas of possibility in which they

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were able to enact new ideas within the confines of their context. Taken together, these findings indicate that developing social justice educators requires attention to navigating the practical details of teaching from a social justice lens.

KEYWORDS

chemistry education, praxis, professional learning community, social justice, teacher education

1 | INTRODUCTION

Theory and practice intertwine to form a reciprocal praxis (Freire, 1974) by which educators act on their ideas and reflect on their actions to refine their ideas. For many science teachers, their theoretical understandings of social justice arise directly from their own lived experiences. Speaking to the embodied enactment of theory hooks (1994) writes:

When our lived experience of theorizing is fundamentally linked to processes of self-recovery, of collective liberation, no gap exists between theory and practice. Indeed, what such experience makes more evident is the bond between the two—the ultimately reciprocal process wherein one enables the other. (p. 61)

However, the practical constraints of the daily work of teaching can serve to interrupt such a reciprocal relationship, leaving little time for the reflection and iteration of a critical praxis. For social justice chemistry teachers, those constraints can occur in three ways. First, the discipline of chemistry is particularly abstract and requires that students move between differing models and levels of abstraction to explain a concept (Earley, 2015; Johnstone, 1982). Despite some recent efforts to the contrary (Sanford, 2020), the discourse about chemistry within the field overwhelmingly draws on objectivity, modernism, and scientism (Sjöström, 2007). As a result, it can be difficult for teachers, most of whom were not taught chemistry through a social justice perspective, to design instructional tasks that tie abstract chemical concepts to issues of injustice that students encounter. Second, the organizational structure of a school can create external barriers (Allen & Heredia, 2020) that prevent teachers from enacting their desired changes in science teaching practice. These can include features such as high-stakes assessments or the way instructional time is allotted for science, which can leave teachers without the time or administrative support to make changes. Finally, even for teachers who have the ideas and the institutional support, there is limited professional development available that specifically supports teachers in integrating social justice and chemistry education.

This paper investigates a professional learning community (PLC) of in-service educators that sought to fill this need by creating intentional space for social justice chemistry teachers to theorize, enact, and reflect. In doing so, they were able to consider how their personal theories of social justice informed their approaches to what is sometimes regarded as the minutiae of practice. In this paper, I investigate how their discussions of practice served to expand their understanding of social justice, narrowing the reciprocal gap between theory and process. From this analysis, I draw conclusions about the pressing practical questions that have the potential to create barriers for social justice teachers as they work to bridge their theoretical understanding of social justice and the daily work in their classroom and the ways that the PLC worked collectively to navigate them.



2 | LITERATURE REVIEW

Social justice science teaching is a broad category that encompasses many theoretical ideas. While different researchers highlight different nuances of the process of teaching science for social justice, the varied conceptions are linked by their commitment to using the act of science teaching to enact more just outcomes on multiple levels—within classrooms, within communities, and globally. This involves attention to equity and disciplinary framing within the classroom (Carlone et al., 2011; Patterson, 2019) as well as the development of a sociopolitical consciousness that demonstrates an understanding of the systematic injustices that exist throughout our societal systems (Madkins & McKinney de Royston, 2019). Other conceptions highlight the role of student agency (Calabrese Barton, 2003) in social justice teaching, using frameworks such as Youth Participatory Science (Morales-Doyle & Frausto, 2021) to foster student engagement with social justice science issues. Finally, social justice science teaching requires that educators challenge existing ideas of the nature of science that contribute to narrow conceptions of science identity (Avraamidou & Schwartz, 2021; Sjöström, 2013). Despite recent efforts to integrate these social justice theories into conversations about classroom practice (NSTA, 2022), available resources remain general and difficult to map into the daily work of the classroom.

2.1 | Ideological commitments in social justice science teaching

In recent years, several researchers have investigated the process of social justice science teaching within chemistry in particular. Vincent-Ruz (2020) draws on border crossing theory to lay out a theoretical framework for emphasizing equity and justice in the development of chemical thinking. This framework highlights the challenges of “epistemological border crossing” (p. 69) when there is significant mismatch between a learner’s resources, the learning environment, and chemistry culture. The author advocates for implementing teaching strategies and learning environments that lessen the difficulty of these border crossings, allowing students to engage with chemistry content without leaving behind their marginalized identities. While the framework gives some examples of pedagogical application, such as designing adaptive laboratory classes that are inclusive of students with disabilities, it is primarily theoretical. Ashby and Mensah (2020) use the findings of an ethnographic analysis of a critical chemistry course in a private, suburban high school to argue that critical chemistry education requires “(1) developing the ability to critically analyze the products of science for the potential of oppression, (2) developing an understanding of inequity in science, and (3) evaluating and respecting diverse knowledge bases” (p. 328). While Vincent-Ruz and Ashby and Mensah focus their conceptualizations on different target populations, both highlight the importance of problematizing the existing inequities in the field of chemistry and broadening our understanding of the forms of knowing that contribute to the science of chemistry.

Working toward these ideas of social justice in teaching requires introspection on the part of teachers to clarify their own ideological commitments and how they connect to the work that they do. Morales-Doyle (2019) argues against a political tendency toward a neutralized view of justice as merely equitable achievement outcomes:

But when we are not explicit about our moral and political stances, we often position the acquisition and application of scientific knowledge as good in and of themselves. Taking a justice-centered approach encourages teachers and students to ask questions about the moral and political implications of scientific knowledge production and application. (p. 489)

Here, Morales-Doyle calls on teachers—and their students—to critically investigate the larger ethical assumptions of the scientific enterprise. Put together, these conceptions highlight the complexity of the work of social justice educators. Social justice educators need to continually expand and clarify their own understanding of the sociopolitical systems in which they work. They need to develop the day-to-day lessons and procedures that

engage students in these questions while also building their content skills. And, finally, they need to do all of this while navigating “the complex bureaucratic structures within which teaching and learning occur” (Roegman et al., 2021). This can easily become an overwhelming task, and educators require—and deserve—support in the process.

Although I note the lack of concrete instructional strategies in these theories of social justice, that is not inherently a problem. First, theorizing is necessary for making sense of how education, injustice, and student experiences are intertwined. Articulating those ideas is a key step toward understanding social justice in the science classroom. Second, an overreliance on naming pre-defined pedagogical practices risks falling into what Bartolomé (1994) calls the “methods fetish.” She argues that uncritical application of even the best-intentioned methods can undermine the very outcomes that those methods aim to support. Instead, she asserts that educators need to engage in ongoing reflection “which allows them to recreate and reinvent teaching methods and materials by always taking into consideration the sociocultural realities that can either limit or expand the possibilities to humanize education” (p. 177). Acting for justice must take into account the specific sociocultural realities of a teacher’s temporal, spatial, and positional context. To “recreate and reinvent” for their own classrooms, though, teachers need support.

2.2 | Practical considerations in social justice science teaching

The tension between wanting to teach for social justice and the realities of school systems is a recurrent theme across many studies (Reagan & Hambacher, 2021). Even when teachers are able to discuss their ideas of social justice and critique the injustices of the existing education system, they often find that making changes within those systems becomes an overwhelming task. Educators need to have reflective knowledge of their own personal experiences as well as knowledge of their students’ lives and cultures (Goodwin & Darity, 2019; Patterson et al., 2017) to understand what social justice teaching means in that specific context.

2.2.1 | Challenges of becoming a social justice educator

Several studies have documented the challenges of embracing a social justice stance toward science education. Rivera Maulucci (2013) investigated the case of Nicole, a Black Caribbean preservice teacher who aspired to become a social justice chemistry teacher. Maulucci argues that “Teaching for social justice requires teachers to: (a) identify justice issues that impact underserved students; (b) reflect in productive (non-deficit) ways about justice issues, including causes, effects, and solutions; and (c) respond through action in the field or personal goal-setting” (p. 456). Maulucci explores Nicole’s emotional connections to learning chemistry as a source of liberation and how those emotions drive her positioning as a social justice teacher. The author found that “knowledge of Chemistry empowered Nicole, and she wanted her students to be empowered through their knowledge of Chemistry” (p. 464). Maulucci makes the case that a teacher’s emotional and ethical commitments influence their ideas about social justice, and that teacher education must consider how to support teachers’ emotional labor and wellbeing as they learn to teach for social justice. Without such supports, teachers can become frustrated or overwhelmed, moving away from efforts to teach for social justice.

Tolbert et al. (2021) focus on in-service teachers to identify ways that two teachers navigated institutional tensions to teach science for social justice. In this paper, which is co-authored by the two women of color whose experiences are portrayed, they begin with pedagogical practice to establish a theoretical framework of critical feminist praxis for school science. In doing so, they demonstrate an application of the embodied practice to the social justice theory arm of the reciprocal relationship between social justice theory and social justice practice. In this study, Tolbert et al. (2021) described how the teachers navigated “rigid spaces” by, among other methods, influencing other teachers’ practice, seeking professional resources, and taking on leadership roles (p. 140). Without



minimizing these challenges, the authors also highlight the possibilities that can emerge when teachers have the time and supports to learn how to navigate them.

2.3 | Developing a social justice teaching practice

Cochran-Smith (2009) argues that “a theory of teacher education for social justice must have a well-theorized idea about the kind of teaching practice that enhances justice” (p. 454). However, research suggests that there is often a gap between theories of justice and theories of justice in practice. In an examination of preservice teacher education classrooms, Kavanagh and Danielson (2020) found a contrast between how preservice teachers analyzed pedagogical decisions related to social justice and those related to core practices of teaching. While the preservice teachers engaged in rehearsals of high-leverage practices, breaking the practices apart to examine how they were implemented, their conversations about justice remained at a theoretical or conceptual level. In analyses of their teaching videos and reflections, researchers found that teacher candidates rarely identified moments where they made decisions based on social justice theory. From this observation, they argue for the importance of attending to the specifics of social justice-centered decision-making within teacher education.

Other researchers have argued that an over-reliance on core practices in teacher education can make justice “peripheral” (Philip et al., 2019) by advancing a prescriptivist approach to teaching practice that neglects the complexities of contextually situated injustices. The authors argue that “promising to address long-standing inequities while remaining silent about the societal processes of oppression that shape and are shaped by schooling risks reproducing historically rooted and contemporary forms of injustice” (p. 8). In a program designed to directly address such processes of oppression, Louis and King (2022) investigated a research-practice partnership that centered abolitionist teaching and community cultural wealth in a preservice science teaching methods course. They found that participants designed lessons that honored students’ cultural capital and engaged students in critical readings and discussions to broaden their understanding of what matters in science. However, it is important to note that these lessons were conducted in microteaching experiences intentionally chosen to “test out new approaches without accountability pressures related to high-stakes testing” (p. 219). In addition to developing the skills to create such lessons, in-service teachers are required to navigate within the pressures created by accountability testing. Bridging such tensions is necessary to make sure that such emancipatory lessons are not just designed, but also enacted.

3 | THEORETICAL FRAMEWORK

While there exists some research on long-term professional development as a tool to support social justice science teaching (e.g., Chen & Moore Mensah, 2022), much of the empirical research on social justice teaching described above focuses on short interventions or preservice preparation. There is an important need to understand how in-service science educators, working over time to integrate social justice into their teaching practice, navigate the tensions between their developing ideas and their school contexts. Learning from these teachers can provide both preservice and in-service teacher educators with additional information about how to support teachers in moving from social justice commitment to enactment.

The term *social justice* itself has become a widely used, and at times contentious, phrase in recent years. While it has been theorized within education (Gewirtz, 1998), and science education in particular (Barton, 2002), for decades, it has also been critiqued as a term often used broadly and imprecisely (Philip, 2012). Therefore, it is necessary to articulate the theoretical roots that I use to define my use of *social justice* in science education. Gewirtz (1998) outlines a theory of social justice that is framed by both distributional and relational dimensions, arguing that both are necessary for theorizing social justice in education. Similarly addressing the role of relationships in working

toward social justice, Barton, (2002) describes a commitment to social justice as “a question of orientation” (p. 17) that is marked by direct interpersonal interactions and navigating relations of power within schools. In defining a theory of teacher education for social justice, Cochran-Smith (2009) identifies three key ideas: (1) equity of learning opportunity, (2) respect for social groups, and (3) acknowledging and dealing with tensions (pp. 454–455). She contends that it is critical for teachers to learn to “directly acknowledg[e] the tensions and contradictions that emerge from competing ideas about the nature of justice and manag[e] those in knowingly imperfect, but concrete ways” (p. 455). Across each of these theorizations, the authors identify both the need for concrete outcomes that improve people’s lives and the importance of ongoing, interpersonal work that identifies and addresses unjust power dynamics.

In this study, I use the framing of *social justice* purposefully to describe a commitment to justice within chemistry education that includes but is not limited to incorporating *social topics* in chemistry teaching. *Social justice* encompasses the need for chemistry education to both connect instruction with lived experience (the *social*) and upend ingrained disparities in the practice and impacts of chemical research (the *justice*). Therefore, I am defining social justice in chemistry education as a *stance*, not a *strategy*. By this, I mean that I am not seeking to name a single set of teaching practices or curricula that “do” social justice. As opposed to a static idea of social justice that becomes an evaluative checklist by which teachers and lessons can be assessed, this research study grows out of an understanding of social justice as spatially, temporally, and relationally shaped. Drawing on ideas of Third Space (Gutiérrez, 2008) and sociocultural learning theory, I argue that social justice is created within the interactions of teacher, student, curriculum, and culture. Drawing on the thinking of Dr. Martin Luther King, Jr, who wrote that “justice at its best is love correcting everything that stands against love” (King, 2010, p. 38), I argue that teaching chemistry for social justice is teaching chemistry from a place of love for students and the world in which they live.

To support the development of their ideas of “the kind of teaching practice that enhances justice” (Cochran-Smith, 2009, p. 454), the PLC design for this study centered around problems of practice identified by the teachers themselves. Following a participatory action research framework (McTaggart, 1991), teachers and researcher then collaborated to investigate the questions that were identified, identify potential ways forward, and reflect on the resulting outcomes. The process of identifying problems of practice and investigating different ways to approach them provides an important opportunity for teachers to generate new knowledge and strategies (Mertler, 2021) while also supporting their professional autonomy as educators (Vaughan & Mertler, 2021). Teachers in this study were asked to bring a “problem of practice related to social justice” to share with the PLC, but they were not given guidelines on what types of problems they should share or how to define “related to social justice.” In part this was because I sought to learn from the kinds of connections the teachers would make when not given specifications of what constitutes a legitimate application of social justice to chemistry teaching. However, it was also a purposeful choice to let those decisions come from the teachers themselves. By positioning current classroom teachers as the source of those connections, rather than manufacturing potential connections for them to seek out, I was intentionally creating an environment where the teachers’ questions were viewed as legitimate expressions of professional expertise. The openness of the task allowed teachers to discuss the issues they most cared about, rather than evaluating fidelity to someone else’s definition of social justice.

3.1 | Researcher reflexivity

By choosing participatory action research as a method (McTaggart, 1991), I made a purposeful choice to ground this research study in a tradition of research that *acts* rather than research that *observes*. Participatory action research serves to “explore the tensions and contradictions between education and schooling as they emerge at particular times and in particular places, to contribute new, evolving and historically appropriate answers to the question ‘education for what?’” (Kemmis, 2006). Such research, while it has the potential to build critical knowledge that manifests both changing practice and challenging ideas, can also become an extension of the researcher’s existing



ideas about practice. This can occur when the researcher sidesteps the problematization of the larger questions of schooling and education, resulting in a process that is technical rather than critical. To mitigate this possibility, I took purposeful actions to ensure the methodological rigor of the study, including reflecting regularly on my own positionality as facilitator and researcher and engaging in member checking following the data analysis.

In this research project, I inhabited multiple roles. As the facilitator of the PLC, I recruited participants, sent email reminders for meetings, and kept time during sessions. I occasionally participated in the discussions, although I tried to minimize my comments to let the participants drive the conversation. As I analyzed the transcripts, I found that in early sessions, motivated by a desire to fill the awkward silences of a newly formed PLC, I often tried to start the discussions after the vexation was presented. In later sessions, as my own confidence and that of the participants grew, I tended to speak less often. While I designed the study to facilitate teacher sharing of expertise, my own role as researcher-facilitator created an inherent hierarchy (Carlone & Webb, 2006) that I sought to constantly examine.

Research Questions

1. What did the chemistry teachers within this PLC identify as problems of practice related to social justice?
 - a. How did these teachers describe the challenges and successes that emerged as they sought to address those problems of practice?

4 | METHODS

4.1 | Study context and participants

Participants consisted of five teachers (see Table 1) located in California and the Midwest. The teachers were recruited by reaching out to participants in previous Chemistry for Social Justice workshops facilitated by the author and identifying teachers who were interested in participating in a more intensive year-long learning group focused on integrating social justice into chemistry teaching. In the previous Chemistry for Social Justice workshops, held over 2–3 days in the summer, teachers reflected on their own understanding of social justice through mind-mapping exercises that served as a means to surface and wrestle with the tensions (Cochran-Smith, 2009) between conceptions centered around access and equity and those focused on the recognition of the ways that chemistry has excluded or harmed minoritized populations. They then brainstormed potential phenomena that might support a social-justice-focused chemistry unit and worked in teams to draft a short series of lessons that they could implement in their classrooms. The workshops included a follow-up day in the winter where teachers revisited their plans and participated in a protocol for looking at student work produced as part of their social-

TABLE 1 PLC participants.

Name ^a	Racial/ethnic identity (self-identified)	Gender	Years of teaching experience	School type
Susan	White	Female	36	Public
Stephanie	White	Female	20	Religious Independent
Candice	White	Female	20	Independent
Bethany	Biracial Asian/White	Female	6	Charter
Salma	Arab	Female	1	Pilot

Abbreviation: PLC, professional learning community.

^aAll participant names are pseudonyms.

justice-focused lessons. The PLC was designed to facilitate an extension of those discussions as teachers sought to develop additional ways to enact their social justice commitment within their classrooms. It is important to note here that, although the process of putting the group together followed a strict protocol, my own role in both the summer workshops and the yearlong PLC makes it likely that the teachers who chose to participate were those who had already formed some rapport with me during our previous interactions and who shared similar, although not exactly identical, ideas about social justice. While the five participating teachers represented a diversity of experience levels, geographic regions, and types of schools, they were relatively aligned on the importance, if not the mode of implementation, of social justice.

All five teachers who chose to participate remained in the PLC throughout the year, although some missed occasional meetings due to other commitments. A PLC was chosen as the professional development strategy for two reasons. First, the small size of the group (five teachers) would allow for the development of personal relationships and trust that are critical for navigating potentially damaging tensions within professional development spaces (Finkelstein et al., 2019). Second, the ongoing meeting cycle would support the goals of participatory action research by allowing teachers to iterate, raise ideas, and return to them throughout the year.

The teachers were drawn from varied school types (public, religious independent, independent, and charter) and locations (Northern and Southern California as well as the Midwest). This allowed them to share examples and challenges across varied contexts (see Table S1 for more detailed school demographic information). All teachers demonstrated an interest in applying social justice to their classrooms. Thus, this participant group was able to draw from and ask questions about their own experiences of incorporating social justice into their chemistry instruction during the group sessions.

4.2 | Data collection

Data were collected as part of a professional learning group conducted via the videoconferencing software platform Zoom. The group met seven times over the course of the school year (Figure 1) and the primary data source was recordings of those meetings. Each PLC meeting lasted approximately 1 h.

In addition to the group meetings, teachers participated in two semi-structured interviews which lasted approximately 30–60 min, depending on the participant's responses. The first, conducted during April 2020 as they transitioned to emergency remote learning, included questions such as “What does your school week look like now?” and “As a teacher, what do you think is most important for you to be doing right now?” The second, conducted at the end of the 2019–2020 school year, allowed teachers to reflect on their participation and learning during the course of the group and included questions such as “How has your overall vision of strong chemistry instructional practice changed this year?,” “How has your overall vision of social justice in education changed this year?,” and “What goals do you have for your teaching next year?” After each PLC meeting, attending teachers

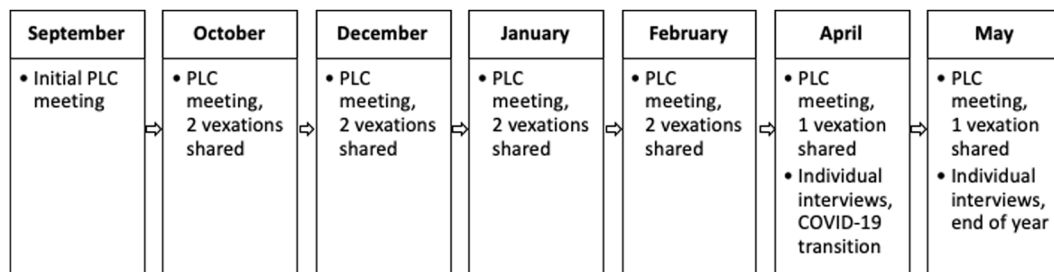


FIGURE 1 Professional learning community (PLC) timeline (2019–2020).

completed post-meeting reflections using a Google Form. The prompts for this reflection included “As a result of this meeting, I am thinking about...” and “Something I will try before the next meeting is...” These data allowed me to gain insight into the teachers' own perceptions of their growth across the year. In addition, I recorded analytic memos (Emerson et al., 2011) after each session and each interview, which were used to identify emergent key themes of each session and provide context for analysis.

4.2.1 | Vexation protocol

During each meeting, two teachers posed a question and received feedback, using a structured protocol distributed to all teachers before the initial session (Figure 2).

The discussion protocol used in the meeting was based on a vexation and venture format (Settlage & Johnston, 2014), in which one participant outlines a vexing challenge (the “vexation”) in their work and poses potential ways forward (the “venture”). Following the initial description of the issue, the rest of the participants ask clarifying questions. This provided teachers with an opportunity to ask for additional details about the teacher's students and school context. Teachers often used this step of the protocol to reflect on and share similarities and differences across school and student cultures. Then, the rest of the group discussed the issue while the focus teacher listened and took notes without contributing to the discussion. Finally, the focus teacher shared what they learned from observing the discussion and what actions they were considering moving forward. The role of each participant during each phase of the protocol is presented in more detail in Table 2.

This structure was chosen because of its alignment with the research goals of this project. Social justice teaching is action-focused and the vexation/venture protocol allowed participants to focus on the actions (the “venture”) that they

Vexation and Venture Protocol	
Vexation	Venture
<p>A challenge in some aspect of teaching chemistry for social justice</p> <ul style="list-style-type: none"> • Go beyond simply venting • Explain <ul style="list-style-type: none"> ○ the source of your frustration ○ why the issue is so troublesome ○ implications of this vexation if left unresolved • Describe your vexation so others can understand and engage in the problem you are considering 	<p>A course of action you might initiate to resolve, diminish, conquer, or overcome your vexation</p> <ul style="list-style-type: none"> • You should be at a decision point, not already decided • Provide an entry point for others to confer with you • Describe any potential ideas you have considered that will help you push past your vexation
Sharing Your Vexation and Venture	
<p>3 min: Presenter shares context, vexation, and venture 3 min: Group asks clarifying questions 10 min: Group discussion while Presenter listens and takes notes 4 min: Presenter rejoins discussion</p>	

FIGURE 2 Vexation and venture discussion protocol.

TABLE 2 Components of the vexation/venture discussion.

Component	Focus teacher role	Group role
Vexation/venture	Present the context of their vexation and potential actions they are considering	Listen
Clarifying questions	Respond to clarifying questions	Ask clarifying questions to make sure they understand the context and challenges described by the focus teacher.
Group discussion	Listen and take notes	Discuss the vexation/venture and evaluate the proposed solutions; suggest additional solutions or perspectives
Summary	Summarize the discussion and share potential actions moving forward.	Listen

would undertake, aligning with the theoretical framework and methodology used in this study. Second, the vexation/venture protocol creates an environment in which all participants' contributions are valued. As shown in Table 2, all participants play specific roles and different steps of the procedure. This was evident in the end-of-year interviews with teachers where, for example, Candice repeatedly described her experience in the PLC as “empowering.” Similarly, Salma, a first-year teacher, reflected that: “There was structure, but it was easy for me to come to the group with anything that I needed. Which made it so that I didn't feel restricted when I was developing my vexations, or when I was working on other people's vexations.” She had entered the PLC nervous that her own lack of teaching experience would make her a less valuable member of the community. By the end of the year, she had developed relationships with the other teachers that were built on a mutual respect and shared goals. Finally, the vexation/venture structure allowed teachers to isolate and expound on specific problems of practice, which aligns with the research questions driving this study.

In addition to the structured vexation discussion, the other teachers present at the meeting shared what ideas they had implemented related to their previous problems of practice. They gave updates about how they chose to move forward to address their vexation, and reflected on the perceived efficacy of the approach they chose. Over the year, each teacher had two opportunities to complete an iterative problem of practice cycle (Figure 3).

One purpose of using this structured protocol to guide the sessions was to challenge the inherently hierarchical nature of many professional development settings, which can be particularly entrenched in researcher-teacher learning networks (Carlone & Webb, 2006), by centering the expertise of the collective rather than a single person. This was especially important given the wide range of experience of the teachers in the group, as well as the author's role as researcher-moderator. Teachers were not provided with any guidelines as to what constituted a “social justice problem of practice” or asked to focus on a particular type of problem. This was done purposefully to investigate what the teachers themselves identified as important problems of practice when they sought to enact their ideas of social justice in their classrooms and schools. Examples of these problems of practice are provided within the findings section in Tables 5 and 6.

4.3 | Data analysis

First, I organized the videos of each Zoom meeting into event timelines based on the speaker and stage of the protocol (e.g., see Figure 4).

This allowed for analysis across comparable protocol stages of each meeting session. To identify the common problems of practice posed by teachers (RQ1), the first stage of analysis focused only on the vexation/venture (problem-posing) segments of the meeting timelines. For the sake of simplicity, the portion of the meeting where the participant described their problem and potential ways forward is described as their “vexation” throughout the following analysis.

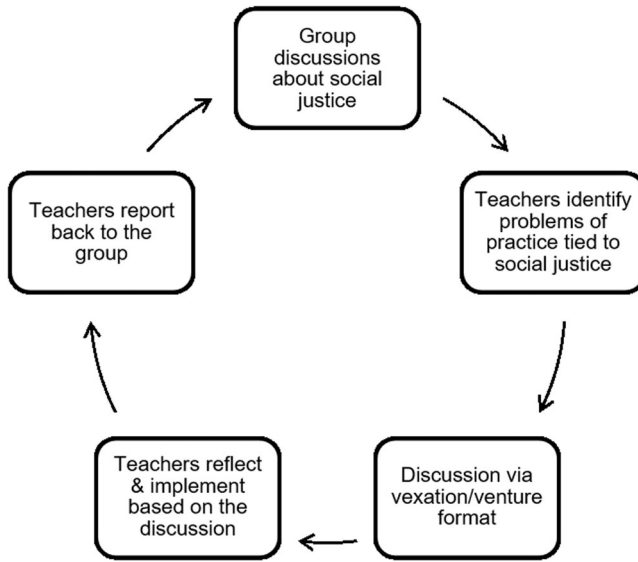


FIGURE 3 Iterative problem of practice cycle.

Update, Susan	Update, Stephanie	Vexation, Salma	Questions, Salma	Discussion	Summary, Salma	Vexation, Candice	Questions, Candice	Discussion	Summary Candice
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FIGURE 4 Event timeline, session 3.

There were a total of 10 vexation segments, two from each teacher, distributed across six sessions between October and May. After I established event timelines, the vexation segments were open- and axial-coded for major themes that emerged in the vexation sessions (Table 3). These codes are not mutually exclusive; for example, one teacher's vexation, about the gender and racial disparities in AP science classes at her school, was coded for discussion of assessment, racial and gender disparities, and collaboration with colleagues. This was because she discussed the assessments used to determine placement as well as the AP exam itself, the disproportionately low number of female and Latine students in the AP science courses, and how her department was working together to develop a coherent solution. Some teachers also referenced a topic multiple times as they discussed different facets of their overarching vexation.

4.3.1 | Case development

Once the vexations were coded and the major emergent problem of practice themes were identified, I used case study methodology to answer RQ1a: How did these teachers describe the challenges and successes that emerged as they sought to address those problems of practice?" From the themes identified in the first data analysis, I identified two representative cases (Yin, 2014) to further examine teachers' attempts to implement social justice in their teaching. For each identified implementation case, I engaged in open coding of the rest of the PLC segments related to the problem of practice and the teachers' statements in their post-meeting reflections and interviews. From this secondary round of coding, I identified cross-case themes and used the data along with researcher memos to write the two narrative cases. I selected contrasting case study teachers that would capture the range of experience and school types represented in the PLC: Bethany, an early career teacher at an urban charter school, and Stephanie, a veteran teacher at a suburban religious independent

TABLE 3 Codebook of vexation themes.

Code	Description	Example
Assessment	Instances in which teachers discussed assessing their students. This includes external assessments and teacher-designed assessments such as projects and tests.	<i>At the end of an exam, then they have an assignment where they're supposed to create their own individual journal that reviews the content and also does some metacognition around how did they study, what did they think about, how did they approach the lesson?</i>
NGSS-aligned curriculum	Instances in which teachers discussed the Next Generation Science Standards (NGSS) or phenomenon-based teaching. Includes statements about needing to or not needing to conform to the NGSS.	<i>So I find it a concern that there are these, I guess these restrictions being placed, and I think it's out of a concern that we start to align to the NGSS and the way they're going to do it is get everyone marching in the same direction without providing the direction.</i>
Collaboration	Instances in which teachers discuss examples of collaboration with colleagues. Also includes instances where teachers express a desire to have more collaboration with colleagues or challenges they encounter when collaborating with colleagues.	<i>And part of that was the structure had been brought by the teacher who brought the project to us from her other school, that's what she had done.</i>
Class time limitations	Instances in which teachers discuss the length of time they have in their class. Includes how much time they have to cover certain tasks or topics as well as general statements about limitations on time.	<i>I feel like I'm always short of time. That's my biggest challenge, I feel like.</i>
Gender or racial disparities	Instances in which teachers discuss gender or racial disparities in their schools or classes.	<i>Our semester exam across the board, I think the boys actually definitely scored better than most of the girls. That's concerning to me.</i>
Technology	Instances in which teachers discussed technology in their classroom. This includes forms of technology being used, distance learning, and student access to technology.	<i>I don't have specific numbers but I was told that not everybody has access at home and with appropriate amounts of tech.</i>
Students' lived experiences	Instances in which teachers mentioned how students' experiences outside of the classroom connect to their learning.	<i>I would be really curious too, and perhaps you've possibly already done this, but learning more about the day-to-day life of the students and what their parents do. What type of issues might be most relevant to them, where you would find the science?</i>

school. However, as I carried out the data analysis, I found that the commonalities in their experiences were especially salient, despite the differences in experience and school profile, and organized the findings accordingly.

5 | FINDINGS

The following two-part analysis describes the tensions that emerged as teachers sought to implement their ideas about social justice. In addition to identifying these potential barriers, I also explored how two of the teachers navigated those tensions as they implemented new instructional ideas.

**TABLE 4** Frequency of themes discussed in vexation segments.

Theme	Pre-pandemic (8 vexations)	Post-pandemic (2 vexations)	Total
Assessment	20	3	23
NGSS-aligned curriculum	14	0	14
Collaboration with colleagues	9	0	9
Class time limitations	1	3	4
Gender or racial disparities	3	0	3
Technology	0	5	5
Students' lived experiences	0	3	3

Abbreviation: NGSS, Next Generation Science Standards.

5.1 | Problems of practice

To answer RQ1, I summarized the themes that emerged in the coding of the participant vexations. In Table 4, I distinguish between vexations that took place before and after the COVID-19 pandemic began to impact schools. Unsurprisingly, the tone and focus of the two post-March 2020 vexations differed greatly from those that took place earlier in the year. Those discussions focused on the unique challenges of adapting to remote instruction and its impacts on students. Two categories, *technology*, and *students' lived experiences*, emerged in vexation segments for the first time in these final sessions of the year as teachers sought to make sense of their commitment to social justice within the context of widespread emergency remote schooling and a public health emergency. While these codes did appear in discussion segments earlier in the year, indicating that they arose in discussions of identified problems of practice, they did not appear when the problems of practice were initially defined. *Assessment* and *class time limitations* appeared in vexations before and after the beginning of the COVID-19 pandemic.

As shown in Table 4, teachers most frequently referenced *assessment* and *NGSS-aligned curriculum* as challenges when posing a problem for the other teachers in the group to discuss. Additional analyses indicated that these were also the predominant themes across all segments of the sessions, most likely because the questions, discussion, and summary content of each session are driven by the issue posed in the vexation segment. This frequency table suggests that these features were most prevalent on teachers' minds as they thought about what it meant to bring their ideals of social justice into their classroom in a concrete way. When examining these topics, it is notable that they define the practical constraints, often imposed from above, that bound the flexibility that teachers have to reimagine their work. When asked to generate social justice problems of practice, the teachers repeatedly identified scenarios in which their goals of enacting a more just pedagogy conflicted with or were subsumed by the requirements of the system in which they work.

5.1.1 | Assessment

For many teachers, equitable assessment was a recurring vexation theme throughout the year, as they sought to find ways to implement mandated exams in ways that allowed all students to demonstrate their knowledge and to incorporate additional, non-test-based assessments into their classroom (Table 5). Participants sought to assess in a way that provided valuable feedback on both content and thinking about the broader impacts of chemistry.

For example, Salma, faced with needing to develop a final exam for 130 students that could be graded within 24 h, worried that defaulting to a multiple-choice exam would not give "equal opportunity" for her students to demonstrate what they had learned during the semester. She brought the vexation to the group hoping for suggestions of alternate projects or exam structures that would give students more agency in how they showed what they had learned.

TABLE 5 Selected examples of assessment as a vexation theme.

Participant, Session	Vexation
Salma, Session 3	Designing a semester final exam that could be graded quickly and would equitably assess student progress.
Candice, Session 3	Writing a rubric to assess student projects that addressed environmental or social justice topics.
Bethany, Session 4	Anchoring social justice science fair projects in chemistry content

Some teachers also raised questions about how to assess projects that incorporated social justice themes or topics. Participants, used to grading more straightforward content exams and lab reports, also struggled to navigate assessing social justice projects where students incorporated their opinions. While they saw projects as a way to connect chemistry to social issues, the challenges of assessing this content threatened to become a barrier to enactment. For example, in Session 3, Candice explained, "I know how to write a test and grade a test, I know how to write a lab and grade that. I struggle with the projects and the rubrics around the projects and feeling like they met the same standards as other types of assessments." Candice found that as she moved to incorporate more opportunities for social connections to content, she was unsure how to design a grading method that allowed for creativity and flexibility while also "holding them accountable to the same level [of content rigor]." Similarly, as Bethany shared about her decision to have students research a social issue for the mandatory school science fair, she asked "How do I anchor it in chemistry and in the science?" In each of these examples, teachers were trying to bridge the conflict between their commitment to social justice teaching and the expectation that they conform to the requirements of the educational system, touching on conflicting ideals about the purpose of science education.

5.1.2 | NGSS-aligned curriculum

Alignment to the Next Generation Science Standards (NGSS) emerged as the second most prevalent source of tension between social justice in theory and social justice in practice. Teachers were encountering the shift to the NGSS in different ways (Table 6). Some teachers mentioned the freedom that they had because they were not tied to NGSS performance expectations (PEs), while others found that the philosophy behind the NGSS was better aligned with their own ideas about social justice science instruction than previous standards had been.

For example, Stephanie felt that her school's decision to redesign the curriculum to align with the NGSS presented an opportunity to work with colleagues to incorporate other shifts in the curriculum. In Stephanie's case, this took the form of anchoring units in social-justice-related phenomena throughout the year. In Session 5, she explained that she was trying to find "some sort of phenomena that could maybe tie all of those things together; climate change, energy, and yet also have some maybe social justice aspect to it that would get our kids pretty excited about [it]. We'd like to get them doing more maybe student action here, as the year ends." For Stephanie, the curriculum redesign prompted by the NGSS became an opportunity to integrate aspects of social justice ideas into her curriculum as well. In another case, Susan found that she was becoming more constrained as her school moved its curriculum to align with the NGSS. As teachers were asked to standardize curriculum across courses—a move Susan described as trying to "get everyone marching in the same direction without providing the direction"—she needed to find examples of ways to generate buy-in from her colleagues to keep several of the environmental justice projects she had developed. She was excited about the potential for making more social justice connections with the new standards, saying "the NGSS themselves are exciting, and [especially] the fact that climate change is so emphasized," but she was concerned that "now I have to turn around and not just make decisions for my own class, but either convince others or face limitations I haven't heretofore had with what I'm doing." The contrasting

**TABLE 6** Selected examples of NGSS-aligned curriculum as a vexation theme.

Participant, Session	Vexation
Stephanie, Session 2	Selecting an anchoring phenomenon for a unit about electronic structure and bulk scale properties that would be relevant and accessible for students.
Susan, Session 2	Developing buy-in from other chemistry teachers at her school to keep environmental justice projects in the curriculum as teachers standardized projects across courses.
Stephanie, Session 5	Selecting a phenomenon for an atmospheric chemistry unit that would provide opportunities for student action

vexations from Stephanie and Susan in the second session raise an important point that the structural context alone is not what created or limited opportunities for teachers to explore social justice in their curriculum. Instead, the impact demonstrated within these vexations depended on how much agency and support was given to teachers working within the constraints of the standards.

5.1.3 | Vexations after the beginning of the COVID-19 pandemic

In the two sessions immediately following the rise of the COVID-19 pandemic, the topics addressed by the teachers' vexations notably shifted. Two major themes emerged that had not been present in the previous eight vexations: *student experiences* and *technology*. As students were now engaging in lessons from their own homes, the teachers found themselves discussing how they could connect the scientific content of their courses with the outside-of-school experiences of students. While teachers occasionally referred to students' experiences when discussing vexations in the pre-COVID-19 sessions, those references were infrequent and often referred to student experiences that were still linked to school. For example, when helping Susan think of social justice phenomena related to materials science in Session 5, Candice added, "I was thinking even really local, as long as you're also investigating your school's recycling. Like what's in place right now in the cafeteria, in events, in all different places. Are they using compostable cups?" In this example, Candice is suggesting that Susan draw on student experiences when designing an anchoring phenomenon. However, the experience that she is suggesting they connect to takes place inside of the school building rather than in students' homes or lives beyond school. In contrast, in the final two sessions of the year, teachers, like many educators, sought to articulate what justice-centered science education looked like during a pandemic era (Forsythe & Chan, 2021). They raised questions about how remote schooling could become an opportunity to bridge the school and home contexts by showing students where chemistry mattered within their home lives. Given the fervent discussions about science and medicine that were taking place in the public sphere, teachers also questioned how—and if—they should be teaching about the novel coronavirus itself.

Additionally, as contact with students moved from in-person to virtual, technology emerged as a major theme that challenged how teachers were working to apply a justice-centered pedagogy. Teachers grappled with the inequitable access to technology and how it would impact their students' ability to engage in coursework during the final months of the year. For example, during the final session of the year, Bethany shared about the challenges of not being able to monitor students' work in person, saying "I've also noticed that students who need the most help are even worse off because they really have to know how to ask for help. They need some sort of way to articulate what is wrong and what they don't understand before they're even able to get started to understanding." In this instance, Bethany was explaining a particular challenge that she had identified during remote instruction: how to support students who were less likely to volunteer that they were confused when she was not physically able to monitor their work or pull them aside after class. Bethany noticed that not all students used technology in the same

ways, for reasons ranging from internet access to shyness, and she was trying to figure out how to support their diverse needs.

Teachers also compared notes on their schools' expectations around technology and found significant differences across their contexts. In Stephanie's religious independent school, course sections merged into a single synchronous chemistry section of approximately 50 students, while Susan's public school administration prohibited any mandatory synchronous course meetings. Most of Candice's students had home access to high-speed internet, while Salma's school distributed laptops and wifi hotspots to families, with mixed success, in an attempt to equalize digital access. All five teachers discussed concerns about shifting their traditional pedagogy to a virtual format and wondered how best to meet students' academic and social-emotional needs as the COVID-19 pandemic began. Assessment and curricular standards were the practical contexts that drove teachers' vexations through the first parts of the school year; when the immediate practical needs changed, so, too, did teachers' vexation topics. This suggests that the topics that create challenges as teachers seek to integrate social justice are those that define the practical constraints within which teachers must navigate as they innovate within a deeply imperfect system. As institutional priorities and emergent needs shift, so do the constraints that are most likely to create barriers to enacting theories of social justice chemistry teaching. This highlights the importance of ongoing reflection (Bartolomé, 1994) to avoid an overreliance on static social justice teaching *strategies* that can become outdated or decontextualized.

5.2 | Moving from ideas to actions

To investigate RQ1a, I compiled case study narratives of two teachers' iterative problem of practice cycles. In each of these two cases, the teacher identifies a problem of practice that is connected to how they are thinking about social justice in their teaching. These cases provide additional insight into the two most frequent problem of practice themes. Figure 5 summarizes the ideas about social justice and practice that emerged throughout each narrative.

In the first example, Bethany brought a question to the group about how she could design a grading rubric for a social justice science fair project that would support student thinking about both social issues and chemical ideas. In the second, Stephanie sought ideas for an anchoring phenomenon for an upcoming unit. Across both cases, teachers identified a problem of practice that had the potential to hamper the ideas of social justice that they were trying to implement. Each vexation was rooted in the practical constraints of their context and the participants used the discipline-specific advice from the PLC to choose a solution to enact. Based on the discussions, Bethany and Stephanie were able to move forward with their ideas and expand their conceptions of social justice in the process as evidenced by how they decided to implement ideas from the discussion. The details of their implementation are discussed below.

5.2.1 | Bethany: Assessing a social justice science fair project

Bethany began by explaining the context of her vexation, which was primarily coded for *assessment*. Her school had an annual science fair in which all science teachers were required to have their students present projects. The previous year, she had given students an option to have their research tied to a social issue, but this year she had decided to make it a requirement of their project. Bethany summarized her vexation, saying:

I'm doing projects for a science fair where students are researching, it's a research project. They're looking at a social issue that has connections to chemistry. So chemistry is either, something chemistry related is causing that problem or it could be used to solve it. I'm looking for, as they

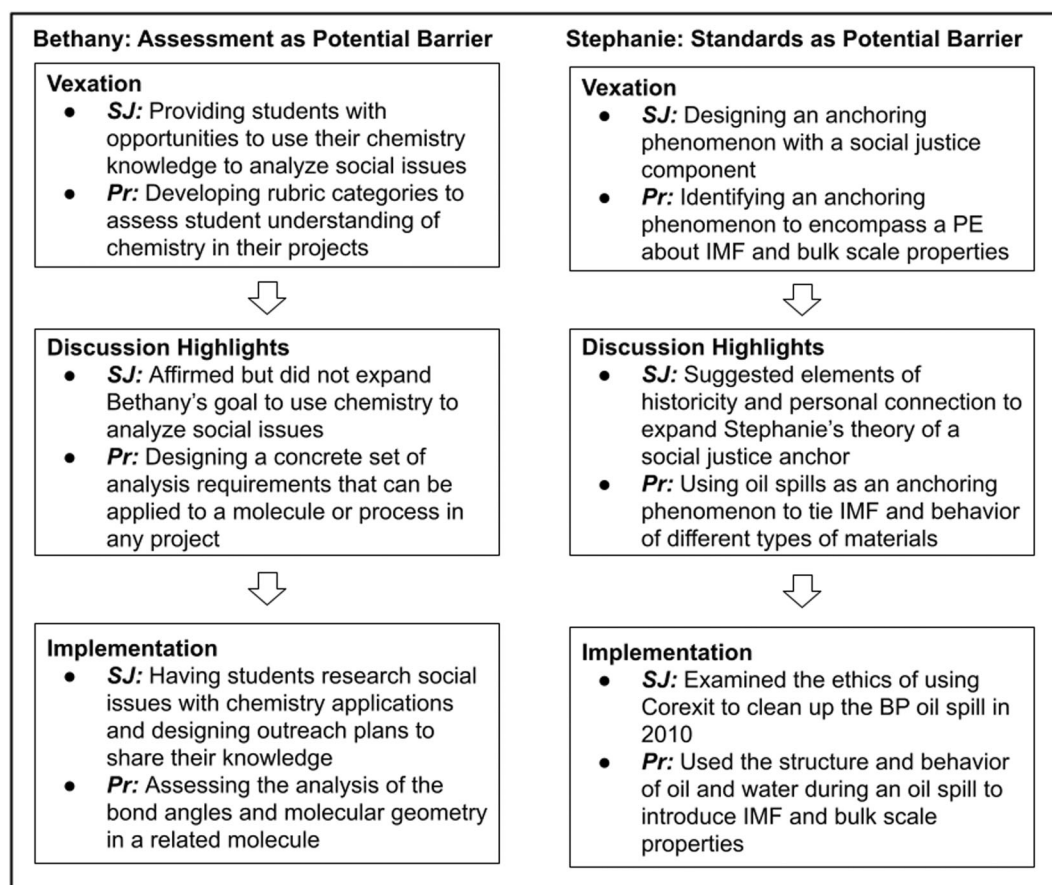


FIGURE 5 Social justice ideas and practical application across cases (SJ = Social justice ideas; Pr = Practice ideas).

present and get ready for the science fair, what are ways to specifically, what categories in a rubric or guidelines in their project I can give them to specifically link chemistry content? Because a lot of times they get, I think, wrapped up in the social issue or just really gloss over the science. Because a lot of times the science is really complicated. So just ideas on anchoring objectives or tasks for kids to keep their projects grounded in chemistry as well.

In this vexation, Bethany asked a practical, discipline-specific question about her idea for social justice science fair projects. She wanted students to connect chemistry to social issues, but she was concerned that the chemistry that they needed to really interpret the science behind the social issues was beyond the complexity level of high school chemistry. Referring to the reactions and mechanisms of the topics students were researching, she added, "Some things are way advanced from what we've learned so far this year." For Bethany, this had been one of the weaknesses of her previous attempt at social justice science fair projects. She explained, "some of the topics were easier to link to chemistry that was understandable to them. And other topics were very broad and so they didn't know how to talk about parabens and how it really affects your skin, in a very complex way." Bethany wanted to identify clear assessment guidelines that would support both her content and social justice goals in hopes of moving past the potential barrier of tying abstract chemistry topics effectively to social applications.

In this project, her goal was to expose students to social implications of chemistry, either in the form of “chemistry causing a problem” or being “used to solve” a problem. However, this created a tension with her need to have consistent guidelines and grading for the assignment, as she worried that a poorly designed rubric would allow students to “gloss over the science.” Avoiding the science content contradicted her belief, expressed in the first session of the year, that part of social justice in chemistry education consisted of helping students “build the skills that they need to be at the table, and help them see that they maybe offer a perspective, that is just as important in forming what science, and all of sciences applications, are.” In this example, Bethany's social justice ideal of using chemistry knowledge as a way to critique real-world applications, a stance aligned with humanizing approaches to chemistry education (Sjöström & Talanquer, 2014), had not met her expectations in the previous year. She identified a potential teacher practice solution, seeking to design an assessment rubric that would support both aspects of the project. Looking for help, she asked the group, “How do I anchor [the project] in chemistry and in the science?”

5.2.2 | Group discussion

After Bethany shared her vexation, the rest of the group discussed possible ways forward. In their suggestions, her colleagues affirmed her questions, provided examples from their own practice, and offered discipline-specific ideas that showed an understanding of the tension Bethany sought to address. Candice began the discussion:

Well, I would just say that, that really resonates with me because it is something that I've struggled with when I've had kids do more open ended projects. And one thing that I have found that is, at least it worked for me, and I'd wonder... I really get that yes, sometimes they pick topics where I think everything is so far out. But what pieces of it can they link to?

In her response, Candice affirmed the challenge of moving to more open-ended projects while still needing to assess student understanding of the topics they employ. She had also experienced students researching topics where the science was “so far out” from the level that the students would be able to explain using what they were learning in class. From this, she pivoted to providing suggestions of ways that she has linked the complexity of a social issue with related chemistry topics.

So, some of the requirements that I've built in is that they have to do some mathematics, they have to do some type of thing ..., types of calculations, energy calculations. Let's say maybe it's not always necessarily energy or specific to bond energy or something like that, but also something around impact. ... And I do put that specifically as something that I'm looking for, that is in my rubric, that they understand it, they can do that.

Candice provided specific, practical examples in her response that speak to the disciplinary question that Bethany asked. She named types of calculations that she has asked students to do and, tying back to the assessment challenge that Bethany raised, stated how she includes it in a grading rubric that is distributed to students in advance. Susan, too, understood the tension between wanting students to explore complex chemistry-driven social issues and needing a clear and consistent means of assessing their use of chemistry. She provided an example of how she had navigated it in the past.

Sometimes when I've had them do something on an environmental theme, I asked that they identify one specific molecule. And then I can ask for some pretty concrete information about the molecule and the formula and the molar mass and the type of bonding, and work in to at least to review some



very basic chemistry content as they work through the... in this case, in the past, it's been environmental issues.

Susan's response was based on both her own disciplinary content knowledge as well as her understanding of Bethany's desire to develop chemistry skills to apply them. She recognized that Bethany needed a consistent task that all groups could be asked to complete that would be flexible enough to be adapted to the different project topics. Candice added that this would be helpful "especially if you're thinking about guidelines for grading." In their responses, the teachers had moved to problem-solving mode with the restrictions identified by Bethany guiding their ideas of how she could navigate the identified social justice problem of practice.

Salma, too, had experienced the challenge of how to assess student application of chemistry to social issues, but she was not happy with the way that she had addressed it in the previous year. She shared an anecdote from her student teaching:

I also did something similar to this almost a year ago, in May of last year. And yeah, I did run into that problem of kids were talking about concepts that they couldn't really get deeper into. Or there wasn't any depth to it or if there was depth, like you said, like it was clearly something that they couldn't explain to a friend type thing, right? I don't, I guess I didn't realize that that problem was occurring. Maybe just out of lack of experience, I didn't realize it was occurring until I was already creating them. And then I felt bad and I didn't want to hold them accountable for the fact that I didn't really clearly explain the criteria.

In this response, Salma demonstrated why Bethany's vexation was so important. Without a clear idea of how she would assess the projects, Salma realized too late that she did not make her expectations clear to her students. Feeling that it was her fault for not "clearly explaining the criteria," she opted to give students full credit regardless of the depth of understanding they expressed. In retrospect, she was not satisfied with that outcome, and she listed several revisions that she planned to try in the future. For Salma, too, the practical task of designing and assessing a project had interfered with her conceptual goal of presenting a transformative vision of chemistry.

5.2.3 | Implementation

After listening to the rest of the PLC discuss her vexation, Bethany shared "That definitely got a lot of things thinking for me. It helped unlock where I was getting stuck." While Bethany had become "stuck" trying to design an assessment that would support her goal of helping students link authentic chemistry content and real-world implications, the ideas from her colleagues helped her consider alternate ways to move forward. At the next session, she shared an update on the social justice science fair.

We learned VSEPR right at the same time. So, they were looking at bond angles and molecular geometry, and it was so good. Just that really simple task, but then they had to do these really complex molecules. They were drawn with organic chemistry, not showing the carbons and not showing hydrogens. They really had to use what they had learned in the simple practice that we had done.

Bethany took up the suggestion to design a uniform analysis task that could be applied across projects. She was pleased with how that allowed her to reinforce the curricular topics. However, once she was able to move past her concern about how to assess the projects, Bethany also expanded how she envisioned social justice in this project by adding opportunities for students to take action related to their project, to engage students in more

consequential learning (Birmingham et al., 2017). She asked students to create an outreach plan to share what they had learned from others. These plans took multiple forms, including Instagram accounts and fliers that allowed students to display their artistic skills. Interestingly, Bethany felt that the structure of a coherent rubric category helped students have a scaffold to design effective outreach strategies. She added:

They were able to share what they had learned with other people in an empowering way versus just here's the project I did on this thing. They really drew connections for everyone who came through [the science fair] of how people could use this topic and this information in real life.

The concrete disciplinary suggestions from the PLC helped Bethany think about how she could implement the social justice science fair in a way that moved closer to her ideals about social justice chemistry instruction. She brought a practical question about assessment rubrics to the group and their targeted responses helped her move from theoretical ideas of social justice chemistry teaching to practical implementation.

5.2.4 | Stephanie: Selecting a social justice anchoring phenomenon

Stephanie shared a vexation with the group that was coded primarily as *NGSS-aligned curriculum*. Her school was in the midst of a curricular redesign, updating its high school course sequence to reflect the groupings of standards outlined in the California science framework. As department chair, Stephanie explained that “in each of the curriculums I was trying to drive forward having every level start with anchor phenomena as well as having a social justice component.” While this was the goal that she had outlined for her science department, when it came to implementing the ideas within the chemistry curriculum she was developing, Stephanie was “still struggling with that, I guess, trying to figure out what we can do.” While she envisioned the new curriculum as a chance to integrate a social justice component into each unit, she found that the details of working with the new curriculum standards were more complicated than expected.

We're very excited about it. But just writing this curriculum has been a labor of love. We'll put it that way. I've spent hours doing it.... Being an older teacher, I'm just old school and like I like a book as a supporting—even an online curriculum would be electronic curriculum, but there just hasn't been a lot developed from the major textbook publishers. ... it's pretty different than what we're used to.

In this example, Stephanie has identified a problem of practice that is driven by the challenge of merging her vision of a “social justice component” in each unit with the reality of the amount of work required to simply update the curriculum to reflect a new way of teaching science. She also worried about “capturing the content in a way that we could make it accessible for all students,” demonstrating the multiple ways that she was thinking about social justice in the context of this problem of practice.

To provide the PLC with enough context, Stephanie gave a detailed explanation of the chemistry content that she wanted an anchoring phenomenon to address.

The performance expectation [is] about electrical structure and bulk scale properties. Which is, of course, teaching about intermolecular forces and it's called electrical forces and bulk scale structure. And if you look at the performance expectation, it says that you're supposed to have student's design something to explore electrical forces and bulk scale structure. We think it's based on IMF, inter-molecular forces and how those determine the vapor pressure of things.



Stephanie was navigating the NGSS PEs for the first time and was uncertain of how some of the PEs connected to the framing she had previously used to teach the topics. Stephanie and her collaborating teacher had come up with “an opening activity where they take a penny and they have to take water and acetone and oil and they drop it on the penny and count the drops ... but we just don't know where to take it from there.” Notably, this opening activity does not demonstrate either a social justice component or the kind of deep, complex science that best shapes an anchoring phenomenon (Lowell & McNeill, 2019). While Stephanie maintained a desire to bring social justice into the unit anchors, she found the actual task more difficult than she expected. At the point that she brought this vexation to the group, the need to target the relevant PE had become a barrier to the implementation of her ideas of social justice. When she could not think of a way to tie a social justice component to the anchoring phenomenon, she chose to prioritize the NGSS standard and was prepared to drop the idea of a social justice tie to the anchoring phenomenon. Notably, at this point, Stephanie was conceptualizing social justice as separate from the NGSS standard, rather than conceptualizing an interrogation of the ideologies expressed within them (Morales-Doyle et al., 2019) as a part of justice-oriented science teaching itself.

5.2.5 | Group discussion

Using information about the chemistry PE and Stephanie's vexation to find an anchor that better fit her social justice goals, Candice suggested a potential unit anchor.

I keep coming back to when you're describing the oil and the water and the intermolecular forces. ... And I'm wondering around if it's possible to look at oil spills and what materials would you use to be able to clean up oil spills and why does that work or how, what types of things have been used in the past or, I don't know, can they construct something or think about it?

Candice was able to use her understanding of Stephanie's social justice and chemistry goals for the unit to propose an anchoring phenomenon that might better fit the unit. Susan agreed with the potential of this idea, adding “I love the idea of materials science. What is it about the stuff we choose to use? What is it that we want? And how does the molecular structure give us that? It's kind of a fun thing to think about.” At the same time, she pushed to expand the way that the phenomenon could support social justice, saying “I was thinking about other connections too, that they might make more closely to their personal life.” In this discussion, Candice and Susan both recognized the potential that had emerged for Stephanie. As she had become concerned about interpreting and applying the new standards, she was having trouble simultaneously maintaining a commitment to her earlier decision to have a social justice component to each unit. Candice and Susan connected to the chemical and social justice needs of Stephanie's vexation to propose a practical solution that refocuses her curricular design. This provided a way past the curricular barrier that she had identified and allowed her to move forward with connecting social justice to the upcoming unit.

5.2.6 | Implementation

The PLC discussion provided Stephanie with the direction that she needed as she sought to make sense of the NGSS PEs. She liked the idea of using oil spills to anchor her next unit, and the discussion sparked an additional idea for how she might incorporate student action. She added, “there might be the potential for student action in terms of going out, I don't know in [our region] if there are, there's probably environmental groups doing cleanup. I mean because we have all those oil refineries up by [city].” Instead of abandoning her plan to bring social justice into the

curriculum rewrite, Stephanie left the meeting reinvigorated. In the following session, Stephanie shared an update about the implementation of her vexation:

I took back the oil spill idea and found some online things and [my colleague] absolutely loved it. So, we did the oil spill... We were talking about the chemical structure of water versus oil that makes them not soluble with each other. And, why is that such a hard thing to clean up oil spills and we also looked at Corexit. the use of Corexit, as BP did.

As with Bethany's example, Stephanie's vexation refocused her on her social justice goals and provided concrete suggestions that she was able to implement. She had students use their understanding of IMF to critique different techniques for oil spill cleanup. Instead of abandoning her existing conceptions of social justice chemistry teaching when she encountered the barrier of the complex PEs posed by the NGSS, she was able to navigate the tension in a way that merged previously separate curricular and social justice plans. She used the idea of oil spills to bring discussions of environmental justice into her unit on intermolecular forces. She expanded on the ideas brought up by the group, bringing in ethical discussions about the use of Corexit in clean-up. (Corexit is an oil dispersant that is often sprayed above oil spills, but it has also been shown to be toxic for sea plants and animals.) Students were able to understand its mechanism of action using the ideas encapsulated by the PE, creating an opportunity to engage in the kind of critical chemistry application (Ashby & Mensah, 2020) that Stephanie had begun the year hoping to spark.

6 | DISCUSSION

While social justice science teaching has demonstrated positive impacts on students' engagement, self-efficacy, and affiliation with science across a range of ages and learning contexts (Ashby & Mensah, 2020; Morales-Doyle, 2017; Patterson, 2019; Patterson & Gray, 2019), the often-flexible definition of the concept can make it challenging to conceptualize implementation against the specific details of chemistry subject matter. Chemistry is a field that is especially abstract (Johnstone, 1982), despite its macroscopic impacts on every process we encounter. It is also dominated by modernist, meritocratic ideals (Sjöström, 2007) which argue that objectivity is both desired in and achieved through chemistry. Imagining a social justice stance within the context of chemistry education is made even more challenging when navigating the bureaucratic systems and ever-spiraling responsibilities of the education system (Reagan & Hambacher, 2021). This paper investigated the problems of practice identified by the teachers within an ongoing PLC to better understand what tensions emerge as teachers move from theoretical commitments of social justice in chemistry teaching to practical enactment of those commitments. The findings provide two key takeaways. (1) Teachers encountered tensions between their theorized ideals of social justice and their ability to practically enact them within their school contexts. To meaningfully engage in teaching chemistry for social justice, they needed to reimagine the practical requirements of their job—grading, lesson planning—from a social justice stance. (2) The small, problem-of-practice-centered PLC created a space for collective teacher learning for in-service educators working to integrate social justice into their teaching practice, lessening barriers that might otherwise have impeded their progress as social justice educators.

This analysis addressed two research questions:

1. What did the chemistry teachers within this PLC identify as problems of practice related to social justice?
 - a. How did these teachers describe the challenges and successes that emerged as they sought to address those problems of practice?



In response to RQ1, I identified seven major themes that emerged in teachers' descriptions of their problems of practice. Of these themes, the most commonly occurring were *assessment* and *NGSS-aligned curriculum*. Two of these themes, *technology* and *students' lived experiences*, only emerged in the two vexations that took place after the beginning of the COVID-19 pandemic. Looking across the identified themes, it is evident that practicality mattered to teachers as they attempted to integrate their social justice stance into the day-to-day procedures of their classrooms. Of the themes, only *gender or racial disparities* and *students' lived experiences* have explicit connections to the tenets of social justice teaching that the participants were trying to employ. Instead, the teachers found that, as they attempted to move toward those commitments, the structural constraints of the systems they worked within often became boundaries that threatened to derail their initiatives. Thus, those structural constraints became especially salient as teachers shared their vexations. These data highlight the importance of professional learning that integrates chances to discuss and apply social justice on a practical basis, since those practical considerations (*But how do I assess this? Can this work with how my school interprets the curriculum standards?*) can become the roadblocks that turn educators away from working to integrate social justice into all aspects of their teaching. To prevent this from occurring, teachers need collaborative spaces to work through these tensions, finding solutions that speak to both their ideas of social justice and the practical considerations that they face.

The unique challenges of teaching during a pandemic led to teachers identifying new equity-centered challenges which, although they emerged in discussions of previous vexations, had not been central to the problems of practice most vexing to the educators. This suggests that changing circumstances can lead teachers to identify injustices that had not previously been a central concern. The problems of practice created by the COVID-19 pandemic (Campbell et al., 2021; Dillon & Avraamidou, 2020) pose new questions, and potential barriers, for educators seeking to bring social justice into chemistry education. The ever-changing contexts in which education lives mean that new questions and implications will arise for teachers as they attempt to enact a more just teaching practice across time, place, and people. In short—the work is never finished and there are no easy answers. Yet, this data highlights the importance of working to explicitly identify connections between theoretical ideas of justice and the very systems that so often work against it. By explicitly navigating those practical details, teachers can find spaces within those systems to enact their ideas of social justice. In this case, the vexation/venture protocol used in the PLC sessions provided a means for these teachers to make such connections.

The secondary analysis to explore RQ1a identified several key findings. As they described potential ventures, teachers generally conformed to the requirements of their context, such as mandatory projects, grading expectations, or academic standards. For example, Bethany was still using the school-approved grading scheme and having her students participate in the science fair. Stephanie aligned her curricular units to the PEs outlined in the NGSS and the sample three-course model offered by the state of California. At the same time, teachers sought to transform those structures by finding ways to make them more equitable (Carlone et al., 2011) or incorporating opportunities to critique the ways that chemistry has been used in harmful ways (Patterson & Gray, 2019). Bethany added a flexible task to make the connection between chemistry and social issues more explicit and asked students to design an outreach plan based on what they learned. In doing so, she demonstrated a theoretical understanding of social justice chemistry teaching which asks students to investigate social justice science issues (Morales-Doyle, 2017) and take action based on what they learn (Calabrese Barton, 2003). She was also concerned with making sure that all students had access (National Research Council, 2012) to interpret the chemical ideas of the topics. In her problem of practice cycle, Stephanie ultimately used the environmental justice questions raised by oil spills to anchor her unit on intermolecular forces and bulk scale properties. In doing so, she placed the microscopic NGSS PE within a macroscopic context to contextualize the need to understand scientific ideas (Gilbert, 2006). Stephanie also asked students to apply a critical-reflexive lens (Sjöström & Talanquer, 2014) by bringing in the example of Corexit, asking them to consider the ethics of when and how chemical solutions are applied to environmental problems. In these examples, the teachers were trying to figure out how to navigate between their social justice ideals and the constraints of their academic context. The problems of practice expressed by each teacher suggest

that their goal was to work within the existing education system's constraints to incorporate their ideas of social justice teaching, rather than create new structures or reject entrenched systems.

By some standards, the sustained focus on practical application within existing systems might represent a failure of imagination of what chemistry education for social justice could become. However, for these teachers, these steps forward represented an important opportunity to try new ideas and evaluate their progress. In her end-of-year interview, Susan reflected on what she had learned, saying "I think this is kind of a lifetime goal and not something that I'm going to achieve in a year." By directing their attention, in both identifying problems of practice and discussing them, to the details that define the work of teaching, the PLC participants were demonstrating their long-term view of the work of social justice. Rather than a single project or topic, they sought to imagine what social justice looked like when woven into all aspects of their work. The work of the group served as a stepping stone for several of the teachers to seek out other opportunities to expand their understanding of social justice education. The following year, Stephanie began a part-time doctoral program in International and Multicultural Education with a Human Rights concentration. Despite expressing that "I didn't want to be a leader," Stephanie also applied for and was accepted to be a part of a school-wide Social Justice, Equity, and Inclusion team. This allowed her "to kind of continue all this thinking and work next year but on a broader scale for my whole school." Bethany ultimately came to the conclusion that the context of her school kept her from doing the social justice work she had hoped to achieve. She made the decision to leave her position at the end of the school year and began working with a district in another state to infuse Indigenous knowledge and environmental justice into their science curriculum. For these teachers, the year-long PLC provided a means to examine and expand their commitment to social justice in chemistry education.

6.1 | Implications for learning to teach for social justice

This research study took a purposefully asset-based stance (Gray et al., 2022) toward teacher learning. This approach draws from sociocultural learning theory to argue that all forms of learning, including learning to teach, "embody complex processes by which people develop discourses and practices that involve speaking, acting, and being in the world" (p. 5). Given this stance, I do not seek to develop a simple standard against which social-justice-oriented teachers should be evaluated. Instead, I explored the processes by which teachers made sense of their conceptions of social justice and how they were navigated throughout the 2019–2020 school year. Framing these conceptions and questions as embodied expertise, I ask how researchers can learn from the expertise and experiences of teachers to better target our own efforts to support them. From this perspective, I identify implications for ongoing in-service teacher learning to support the development of social justice teaching.

First, while understanding the theoretical ideas of social justice, including the sociopolitical context that creates oppressive cultures in science and science education (Madkins & McKinney de Royston, 2019; Morales-Doyle, 2019), is important to developing a conceptual understanding of teaching chemistry for social justice, ongoing support for in-service teacher learning cannot stop there. As this research study shows, without guidance on how to navigate the tensions between their ideological commitments and their institutional requirements, teachers can become overwhelmed by the disparity between their idealized, imagined classroom and the one they enter each day. As a result, these tensions can become barriers that push teachers away from enacting social justice pedagogy in their classrooms (Reagan & Hambacher, 2021). Therefore, in-service teacher education to support teaching for social justice should consist of long-term opportunities that allow teachers to return to their questions about enacted social justice at different points in the school year.

The challenge of transferring social justice commitments to daily teaching practice has been well documented (Goodwin & Darity, 2019; Kavanagh & Danielson, 2020; Roegman et al., 2021). This study suggests that supporting teachers in teaching for social justice necessitates attention to those practical, everyday details, since those are the details that can emerge as barriers to impede their progress. It also suggests that the vexation/venture format for



professional development might be especially valuable for this purpose. These teachers began from where they were, finding small ways to transform while generally conforming to the systems that surrounded them. This indicates that existing requirements and structures do not have to be undone before teachers can begin applying a social justice stance to teaching chemistry. However, identifying and navigating the tensions between context and ideals proved to be an entry point, not a conclusion, to expand their understanding of teaching chemistry for social justice. As the teachers in the study identified these ongoing tensions, they sought to find ways to change those barriers, rather than simply navigate within them. For Stephanie, this took the form of expanding her leadership at her school and seeking out additional education. For Bethany, it took the form of leaving a situation where the barriers became insurmountable for a position where she saw more opportunities impact the context itself. Taken together, this suggests the importance of in-service teacher education that both prepares social justice educators to navigate the daily tensions of their contexts and develops the agency and collective ability to make changes within those contexts.

This study provides evidence that collaborative learning spaces for social-justice-oriented chemistry teachers can help educators apply social justice theory to classroom practice. It was in this space that teachers brought questions about teaching intermolecular forces and molecular geometry, topics that are not immediately apparent as sources of social justice. However, by engaging in a PLC that supported the development of a critical praxis (Freire & Macedo, 1987) through a vexation/venture protocol (Settlage & Johnston, 2014), teachers could discuss both how to engage students in learning to comprehend the structure and behavior of matter and how that understanding could be used to collectively develop a more just world., strengthening their critical praxis. In her end-of-year interview, Stephanie reflected on the strengths of the PLC format, saying: "You had some of us who were very well-established veterans and then others that were fairly new. I felt like we all were there with the same intent, which was to listen and learn and improve our teaching for our students." Similarly, Salma explained: "it really allowed me to work [meshing science and social justice] out with other science teachers." Hooks (1994) wrote that "It is crucial that critical thinkers who want to change our teaching practices talk to one another, collaborate in a discussion that crosses boundaries and creates a space for intervention" (p. 129). For this group of teachers, the PLC provided an opportunity to "cross boundaries" to imagine new possibilities for critical chemistry education. In her end-of-year interview, Candice responded to a question asking how the group had prepared her to connect social justice to science teaching by saying:

I think primarily just by floating different ideas. Also, just the empowerment piece, I think, and validation. To say, "Okay, what does this look like in the science classroom specifically?" I think has been really valuable. I guess, because so many folks that [I] connect with might have deep social justice, they do that work, but just don't have a way to tangibly make a connection into a science classroom in a way that I feel like is relevant and doable. ... And that I feel that piece has been bridged.

For Candice and the rest of the PLC, their discussions created a "bridge" to make a tangible connection between "deep social justice" and application to a science classroom. The participants in the PLC, with shared expertise in chemistry instruction, were able to develop discipline-specific solutions to the social justice problems of practice that they identified. They did not want to replace rigorous chemistry instruction with social justice; they sought to integrate the two. This paper demonstrates the possibilities of collaborative learning spaces in bridging social justice theory and social justice practice.

CONFLICT OF INTEREST STATEMENT

The author declares no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author.

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Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Ribay, K. (2024). Lessons from a professional learning community: Navigating tensions while moving between theory and practice in teaching chemistry for social justice. *Science Education*, 108, 734–761. <https://doi.org/10.1002/sc.21854>