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RESEARCH ARTICLE

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How do organizational conditions inform teachers' equity self-efficacy and implementation during professional development?

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Abstract

This paper is part of the special issue on Teacher Learning and Practice within Organizational Contexts. Shifting instructional practices in elementary schools to include more equitable, reform-based pedagogies is imperative for supporting students' development as science learners. Teachers need high quality professional development (PD) to learn such practices, but research shows considerable variability in the extent to which teachers implement instructional practices learned during PD. Individual teacher characteristics such as self-efficacy may influence teacher learning during PD, but only account for part of the variability. The organizational conditions of teachers' schools and districts may also play a key role in teachers' implementation of new instructional practices. However, because systematic research in this area in science education is still nascent, it is difficult for districts and PD providers to address organizational barriers to professional learning. To meet this need, we conducted an explanatory mixed-methods study using surveys ($N = 54$) and interviews ($N = 19$) of elementary teachers engaged in equity-focused, reform-based science PD, testing the degree to which a conceptually framed set of organizational conditions predicted teacher equity self-efficacy and instructional practice alignment. Out of the 11 organizational conditions, only teacher professional impact and their sense of autonomy in their instructional practice explained variance in the outcomes. Qualitative findings showed these relationships to be iterative and recursive, rather than linear. Our findings underscore the essential role of teacher professionalism and sense of agency over commonly cited organizational conditions such as materials and labs in supporting teachers to implement more equitable science instructional practices during PD.

KEYWORDS

autonomy, equity self-efficacy, organizational conditions, professional development, science education, teacher change, teacher leadership

Providing equitable, reform-based science learning opportunities for our diverse elementary student population is crucial to support students' future growth as science learners as they move through middle and high school (Maltese & Tai, 2010). In such an approach, students engage in knowledge-generation practices as they make sense of phenomena with the teacher and one another (Miller et al., 2018; Suh et al., 2022; Windschitl et al., 2012). Instruction incorporates student lived experience and embraces the variety of languages students bring to the classroom (Bang et al., 2017; Barton & Tan, 2009). Achieving this kind of classroom requires teachers to shift from being arbiters of knowledge to being facilitators of student sensemaking (Odden & Russ, 2019; National Research Council, 2013). Such a shift may be difficult for elementary teachers lacking confidence and skill in science teaching in general and equitable science instruction in particular (Murphy et al., 2007). As a response to this need, science educators have invited teachers to join professional development (PD) efforts that support their learning in these areas (Suh et al., 2022; Maeng et al., 2020). However, even when engaged in well-conceived PD, elementary teachers often struggle to change their instructional practices, and studies show great variation in the degree of uptake and implementation of reform-aligned instructional practices across teachers engaging in PD (Sandholtz, et al., 2019).

In highly diverse contexts, one potentially important influence on how and why teachers internalize and implement equitable, reform-based instructional practices learned in PD is their level of confidence in their ability, or self-efficacy (Lakshmanan et al., 2011; Schipper et al., 2020; Tschannen-Moran & Hoy, 2001). "Equity self-efficacy" has been coined to refer to teachers' beliefs in their ability to support the science learning specifically of students from historically marginalized populations (Ritter et al., 2001). Equity self-efficacy accounts for not only teachers' confidence in teaching science content, but also their confidence in implementing equitable science instruction that attends to students' different ethnic, language, gender, and socioeconomic backgrounds (Ritter et al., 2001). Recently, scholars are also suggesting that teachers' self-efficacy may play a key mediating role in the relationship between PD and their instructional practices (Perera et al., 2019; Seneviratne et al., 2019).

Yet, personal characteristics such as equity self-efficacy only explain part of the variability in teacher implementation of equitable, reform-based instructional practices during PD. Several literature reviews have proposed that many PD studies do not adequately take into account the organizational conditions that influence teacher learning during PD (Boylan & Demack, 2018; Kennedy, 2010; Opfer & Pedder, 2011). Simultaneously, PD providers are seeking ways to address persistent organizational barriers faced by teachers implementing new instructional practices (Allen & Heredia, 2021; Hayes et al., 2023), especially in regard to elementary science, as elementary contexts are often unsupportive of science (e.g., Hayes & Trexler, 2016; Longhurst et al., 2017; Sandholtz et al., 2019). The influence of organizational conditions may have been amplified during the pandemic; many teachers felt a loss of morale and self-efficacy in relationship to the inequities facing their students (Reich et al., 2020) and there is evidence that poor working conditions exacerbated this feeling of ineffectiveness (Khanal et al., 2021; Kraft et al., 2021). These studies demonstrate that additional research is warranted on how organizational conditions shape teacher learning and implementation during PD.

1 | PURPOSE

Understanding salient organizational conditions and how they shape teacher equity self-efficacy and instructional change can help PD providers better support teacher learning of equitable science instruction. A growing number of studies show that certain organizational conditions, such as accountability and principal support, can influence whether and how teachers implement what they are learning in PD within their classrooms (Allen & Penuel, 2020; Banilower et al., 2007; Sandholtz et al., 2019). However, conceptual frameworks that facilitate systematic study of organizational conditions are still in development, and the nature of relationships between PD, various organizational conditions, equity self-efficacy, and instructional change is in development. A mixed methods approach allows us to quantitatively examine the relationships among these constructs as well as to understand the processes that explain the relationships in the quantitative models. In this study, we use explanatory sequential mixed methods to investigate these relationships, analyzing survey ($N = 54$) and interview ($N = 19$) data collected from 3rd to 5th grade teachers participating in a science education PD project during the pandemic. Specific research questions are listed below. The hypothetical model is depicted in Figure 1.

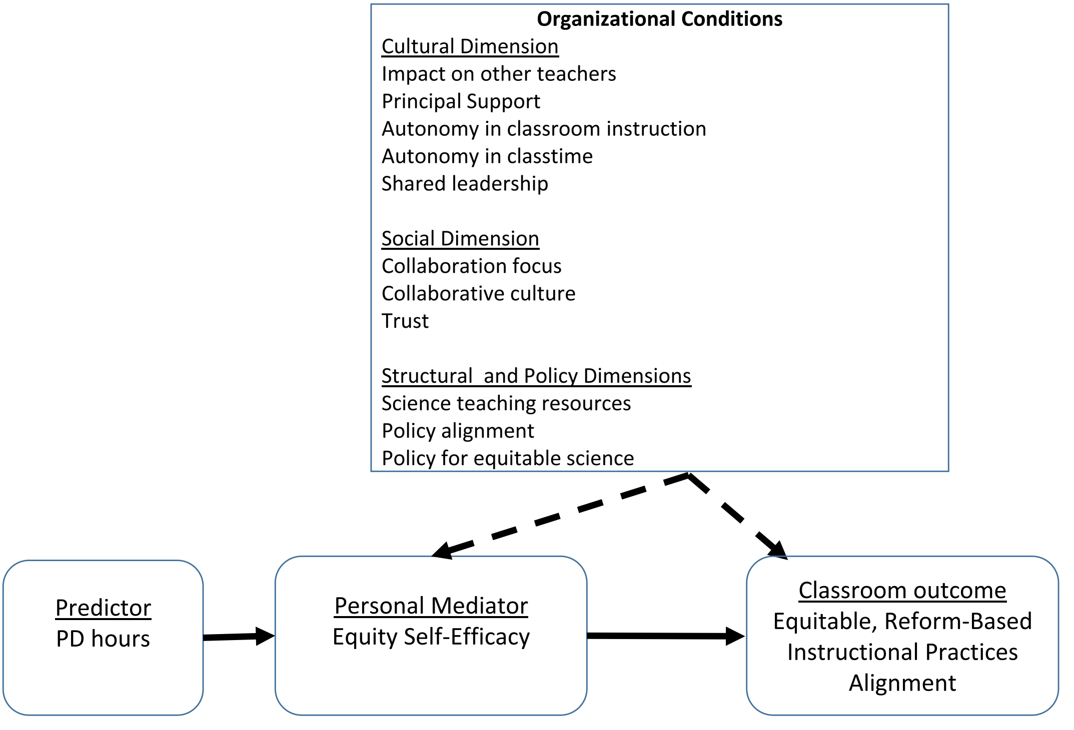

FIGURE 1 Hypothetical model of the relationships between main variables.

1. Quantitative: Does equity self-efficacy mediate the relationship between PD participation and reform-based science instructional practices?
2. Quantitative: To what degree do organizational conditions predict teacher equity self-efficacy and instructional practices in the context of PD?
3. Qualitative: How do teachers' perspectives contextualize and explain the relationships identified in the quantitative models?

2 | LITERATURE REVIEW AND CONCEPTUAL FRAMEWORKS

2.1 | Understanding teacher variability in implementation during PD

2.1.1 | Equity self-efficacy and teacher change during PD

Large-scale studies of teacher PD have found relationships between participation in PD and instructional outcomes, such as inquiry-based practices (Banilower et al., 2007; Granger et al., 2019; Maeng et al., 2020; Pringle, et al., 2020; Fischer et al., 2018). For example, in a randomized control trial examining the effects of science PD for 4th through 6th grade teachers, Maeng et al. (2020) found treatment teachers' understanding and implementation of inquiry-based instructional practice to be statistically higher than that of the control group after 1 year of PD. Although in many of these studies, teachers on average improve their instructional practices during PD, averages mask substantive variation in uptake of reformed instructional practices among teachers engaged in professional learning. Studies have attempted to account for unexplained variance by including variables at the teacher level, such as their self-efficacy, to help explain the relationship between PD and subsequent instructional practices (Banilower et al., 2007; Fischer et al., 2018).

The concept of self-efficacy emerged from Bandura's (1997) social cognitive theory, which seeks to explain how individuals' cognitive, motivational, and behavioral processes interact with their environment to realize desirable outcomes. Higher self-efficacy for teaching has been linked to positive outcomes in science teaching, including teachers spending more time teaching science, spending more time developing science concepts (Lakshmanan et al., 2011; Schipper et al., 2020; Seneviratne et al., 2019), and supporting students in persisting through difficult tasks (Fauth et al., 2019; Perera et al., 2022; Settlage et al., 2009). With the growing call for teachers to implement equitable reform-based science instruction, Ritter et al. (2001) expanded the construct of teacher self-efficacy to focus specifically on teachers' beliefs in their abilities to meet the science learning needs of historically marginalized students. This more specific construct of *equity self-efficacy* is the focus of our study. Teachers may perceive their equity self-efficacy differently than global self-efficacy because the items ask teachers to report on their ability to meet the needs of students as it relates to racial, ethnic, linguistic, and/or socioeconomic factors. For example, Settlage et al. (2009) found that while the primarily white pre-service elementary teachers' global self-efficacy increased over the course of their credential program, their equity self-efficacy started and remained high (perhaps falsely). The literature thus points to the nature of self-efficacy as a complex construct in relation to teacher learning, behaving differently depending on the focus (e.g., equity vs. general), population (e.g., diversity of teachers), and organizational environment (e.g., teacher autonomy; Holzberger et al., 2014).

Despite this complexity, the relationship between high-quality professional learning experiences and increases in teacher self-efficacy is well established (e.g., Lowell & McNeill, 2022; Saka, 2013; Seneviratne et al., 2019; Settlage et al., 2009). In addition, longstanding research has established a positive link between teacher self-efficacy and improved science instructional practices (e.g., Perera et al., 2022; Tschannen-Moran & Hoy, 2001). More recently, scholars have suggested that teacher self-efficacy may play a mediating role between PD and their implementation of reform-aligned science teaching (Perera et al., 2019; Seneviratne et al., 2019). Our study extends this literature by empirically testing a model in which equity self-efficacy mediates the relationship between teachers' participation in an extensive science PD project and their implementation of equitable, reform-based science instruction (RQ1).

2.1.2 | Organizational conditions and teacher change during PD

The success of PD in terms of increasing teacher equity self-efficacy and the implementation of reform-based instruction may additionally be dependent upon the organizational supports that are in place (Hayes et al., 2023; Holzberger et al., 2014; Opfer & Pedder, 2011; Sandholtz et al., 2019). Such supports are particularly important to take into consideration during the pandemic, due to the disruption and increase in inequities caused by COVID-19 (Reich et al., 2020). Yet very few studies regarding teacher changes in self-efficacy or instructional practice during PD have examined the role of organizational conditions (Boylan & Demack, 2018; Fackler & Malmberg, 2016; Kennedy, 2010; Opfer & Pedder, 2011).

The small number of quantitative studies that have examined organizational variables as predictors of teacher self-efficacy as an outcome show mixed findings. For example, Schipper et al. (2020) used a quasi-experimental design to examine how participation in lesson study affected teacher perceptions of self-efficacy and school organizational conditions ($N = 60$). They found that the treatment group (lesson study) demonstrated increased self-efficacy over time compared to the control group (no lesson study), but no relationship between organizational conditions and self-efficacy was identified. On the other hand, Lazarides et al. (2023) examined two components of teachers' organizational context, job demand (i.e., work overload) and job resource (i.e., sense of belonging at school), in relation to their self-efficacy, teacher-student relationship, and value for student engagement. Results showed that the job resource was associated with self-efficacy early in their career, and job demand undermined the positive effect of teacher self-efficacy on teacher-student relationship and teacher value for student engagement (Lazarides et al., 2023). Taken together, emerging results indicate complex and dynamic relationships among teachers' self-efficacy and organizational contexts, warranting further investigation.

Other studies have begun including organizational variables as predictors of instructional practice during science PD. As an example, two related studies found a small but significant effect of school resources and administrator support on teacher instructional practices in the context of science professional learning (Banilower et al., 2007; Supovitz & Turner, 2000). That said, because they included no other variables for organizational conditions, it is unknown how these conditions performed compared to others. Schipper et al. (2020) incorporated elements of school culture (e.g., collaborative materials development) as well as conditions (e.g., collegial support, favorable policies) in their quasi-experimental study on teacher change during lesson study. They found teacher perception of both their autonomy (e.g., teachers have a say in educational materials) and leadership support increased in the intervention group over 1 year, but no other relationships among variables. This is a promising study, yet most other quantitative studies that incorporate organizational elements beyond population characteristics rarely include more than one or two variables, and thus cannot effectively compare the relationship between various aspects of the organization and instructional practice. Given that teachers are typically embedded within a larger organization (i.e., school) with associated mandates, resources, incentives, and norms, it is likely that these more complex organization variables have a relationship with teachers' perceptions of their abilities to teach and their alignment in instructional practices, and thus should be included as predictors.

Additionally, the pandemic precipitated immense changes to the typical organizational conditions that teachers were operating within. There was broad variation in the immediate and more long-term response from school leaders in moving instruction online, prioritizing curriculum components and activities, leveraging technologies, and modifying instructional practices to align with health and safety concerns (Khanal et al., 2021). Numerous studies point to the ways that the pandemic heightened challenges for teachers and exacerbated existing educational inequalities, impacting student engagement, teacher morale, and work-life balance (Kraft et al., 2021; Trinidad, 2021). In their scoping review of organizational responses to the pandemic, Khanal et al. (2021) found that teachers' working conditions played a substantive role in their feelings of success (self-efficacy) during the pandemic. Teachers who felt that their school and district offered strong communication, fair expectations, recognition for their efforts, and support for PD and collaboration were less likely to lose confidence in their ability to support students during this difficult period.

Building upon this important work, in RQ2 we examine the role that a conceptually specified set of organizational supports may play in teachers' equity self-efficacy and alignment of their instructional practices with equitable, reform-based science pedagogies. In addition, we examined whether teacher equity self-efficacy mediates the relationship between organizational conditions and implementation of reform-based instruction while taking into account participation in PD.

2.2 | Conceptualizing organizational conditions

Although some organizational conditions are implicated in recent literature on science PD (e.g., accountability, principal support), conceptual frameworks to guide such inquiry are underdeveloped, hampering a systematic approach to understanding the nature and roles of particular organizational conditions on teachers' development and classroom practice. To organize the various organizational conditions that may affect professional learning, self-efficacy, and instructional practice in science education, we use a framework called the instructional capacity framework (Hayes et al., 2020). This framework was built on Mitchell and Sackney's (2011) work on capacity for professional learning communities, as well as other foundational research on reform capacity (Hatch, 2013; Spillane & Thompson, 1997). The instructional capacity framework uses an ecological approach to conceptualize elements of capacity, and we use four dimensions at the organizational level to conceptualize and frame this study: the cultural, social, structural, and policy dimensions. Within those dimensions, we summarize the literature for organizational conditions shown to affect teacher self-efficacy for equity, their ability to learn from PD, and their science instructional practices.

The ***cultural dimension*** consists of collective norms and leadership approaches within the organization (Leithwood & Mascall, 2008). Aspects of organizational culture have been shown to have a powerful impact on teacher learning and implementation of new instructional practices (Longhurst et al., 2017; Louws et al., 2017). An important facet of organizational culture is the interplay between teacher degree of choice in instructional practice and classroom organization (teacher autonomy) (Schipper et al., 2020), teacher ability to influence the organizational or instructional culture (shared leadership or impact) (Leithwood & Mascall, 2008; Short & Johnson, 1994), and collective vision of reform (Longhurst et al., 2017; Spillane et al., 2001). All three have been shown in various studies to influence teacher learning, teacher self-efficacy, and/or instructional practice (Holzberger et al., 2014; Longhurst et al., 2017; Schipper et al., 2020), although they are rarely examined together. Specifically, teachers may need a certain degree of autonomy in their classroom instruction to develop ownership of instructional reforms (Davis, 2003; Szelei et al., 2020). Such autonomy may be particularly important in organizational contexts that are antithetical to equity or that discourage science teaching at the elementary level (Gutierrez, 2016). However, in most cases, to support instructional reform, autonomy must be coupled with equity-focused teacher learning and ongoing collaboration (Fullan et al., 2022; Lamb et al., 2011), lest teachers close their doors and continue teacher-centered instruction in autonomous isolation.

Principal support and leadership style may also influence the ways professional learning translates into instructional reform, in part through influencing self-efficacy (Banilower et al., 2007; Fackler & Malmberg, 2016; Pringle et al., 2020). Yet, this relationship is not demonstrated consistently across studies (Fischer et al., 2018; Schipper et al., 2020), possibly due to administrators focusing on management instead of pedagogy (Rigby, et al., 2017), or lack of knowledge of subject specific pedagogies, such as the science and engineering practices (McNeill et al., 2018).

The ***social dimension*** encompasses the networks of relationships among teachers, administrators, and other people within an organization, often described as social capital (Adler & Kwon, 2002; Coleman, 1988). In schools, relationships that serve equitable teaching are fostered through collaboration focused on student learning and the instructional practices needed to support it. Such collaboration creates channels of communication whereby instructional expertize is shared and built (Coleman, 1988; Settlage et al., 2015). Research shows that collaboration influences the ways in which teachers learn professionally and are able to translate such learning into instructional practices (Longhurst et al., 2017; Schipper et al., 2017). Furthermore, any reform focused on science instructional change requires collaboration focused specifically on content and practices specific to the discipline (Longhurst et al., 2017).

The ***structural dimension*** consists of tangible resources, such as curriculum and technology, as well as codified elements of schooling, such as the structure of the school day (Hatch, 2013). The availability and quality of curriculum, textbooks and other instructional materials has been cited by teachers as an important element of their instructional practices, and uneven distribution of quality materials and technology can be a serious equity issue (Sandholtz et al., 2019). At least one study of PD has found that teachers who lack the materials to implement more inquiry based pedagogies simply appropriated the content from the PD and provided it to students in lecture form (Fore et al., 2015). Yet, research on the relationship between structural resources and reform implementation is often mixed and inconclusive, leading to the admonition that such resources may be necessary but not sufficient (Grubb, 2009; Spillane & Thompson, 1997).

The ***policy dimension*** consists of local, state, and national policies that influence structures within the organization as well as teacher beliefs and practice (Malen et al., 2015). When teachers learn in PD, they simultaneously are making sense of how the new instructional practices cohere with multiple and often competing policy goals in their instructional context (Allen & Penuel, 2015; Kazemi & Hubbard, 2008). For example, Fore et al. (2015) found that standardized tests, strict pacing guides and teacher evaluation greatly affected teachers' ability to incorporate new curriculum. Teachers had to negotiate their learning in the curriculum focused PD with their policy environment. Leadership can also be part of the policy dimension through the interpretation and enactment of state and federal policies, and the creation of local educational policy (Pringle et al., 2020; Wenner & Settlage, 2015).

2.3 | Outcome: Equitable reform-based instructional practices

Contemporary science education reforms underscore the importance of engaging students in knowledge-generation practices where students make sense of phenomena through gathering and using evidence, constructing and critiquing explanations, and making arguments regarding scientific ideas (National Research Council, 2013; Suh et al., 2022; Windschitl et al., 2012). In such an environment, student discourse drives the intellectual conceptualization of science ideas as students use multiple forms of language (academic, everyday, community) in collaboration with one another and the teacher (National Research Council, 2013; Odden & Russ, 2019). In these instances, the teacher's role shifts from being an authority on scientific knowledge to a facilitator of students' sensemaking processes as they dialogue with one another (Miller et al., 2018; Windschitl et al., 2012). Further, ensuring that sensemaking opportunities are equitably structured involves the teacher being aware of power relations in science that have historically privileged Western ways of knowing and thinking, and intentionally identifying and elevating the contributions of students from minoritized backgrounds (Bang et al., 2017; Barton & Tan, 2009). Together, these approaches move toward a "teacher as negotiator" approach to learning, in which the teacher promotes the authority of students to generate knowledge as they engage with phenomena and disciplinary ideas (Hand & Cavagnetto, 2023). To this end, the PD in this study focused on supporting elementary science teachers' skills with three-dimensional, NGSS aligned instruction while also attending to features of equitable sensemaking discourse, a set of instructional practices which we hereafter call equitable, reform-based instructional practices.

3 | METHODS

3.1 | Mixed methods design

To answer the research questions, we used an explanatory sequential mixed methods design (Creswell & Plano Clark, 2018). A mixed approach allows us to explore the quantitative relationships among PD, teacher equity self-efficacy, instructional practices, and organizational conditions, as well as the qualitative nature of these relationships (Creswell & Plano Clark, 2018). We first used structural equation modeling to analyze survey data collected from 54 third through fifth grade teachers participating in a 3-year science education PD project. We examined the path between PD hours and instructional practices alignment, mediated by equity self-efficacy. We then tested the relationship between this mediation model and 11 organizational conditions, which we specified based on the instructional capacity framework (Hayes et al., 2020) and related literature (e.g., Longhurst et al., 2017; Schipper et al., 2020). In the qualitative strand, we analyzed interview data to generate a deeper understanding of personal and contextual processes that explain the direction and magnitude of the relationships identified in the quantitative models. The interview sample is a subset of the survey sample, and all data was collected during Spring, 2021.

3.2 | Context

3.2.1 | The PD

Science Learning Partnership (SLP; pseudonym) was a multi-year project designed to build instructional and organizational capacity for elementary science in eight school districts in a densely populated area of California. SLP followed literature consensus regarding the need for PD of sufficient duration that provides active learning opportunities, focuses on content, and allows for collaboration (Desimone, 2009). Additional assumptions that guided the PD approach included the notion that teachers are professionals who bring tremendous knowledge and skill to the table, that they are committed to their students and their profession, and that they need a space where they belong as learners and experts (Osman & Warner, 2020). The weeklong summer institute and three Saturday workshops during the school year were co-facilitated by a science faculty, science instructional coach, and teacher leader. Cohorts of 3rd, 4th, and 5th grade teachers focused on one science content area (e.g., earth, physical, or life science) for a full academic year, rotating to the other content areas over 3 years.

During the year of this study (2021–2022), pedagogy focused on how to use distance technologies to facilitate (at least) two-dimensional instruction with modeling or explanations (National Research Council, 2013; Windschitl et al., 2012), how to leverage the cultural experiences, languages, and other resources that historically minoritized students bring to the classroom to expand access and opportunities to engage in science (Bang et al., 2017; Barton & Tan, 2009; Moll et al., 1992). Teachers engaged in activities and reform-based instructional practices from the perspective of a student, in that they experienced three-dimensional, phenomena-based, discourse-rich learning as their students would (e.g., engaging in an elementary science investigation). Teachers then together constructed an understanding of how to carry these instructional practices into the classroom. Throughout the PD, facilitators invited teachers to discuss and reflect upon their school and classroom contexts and encouraged teachers' adaptation of science lessons and materials in ways that would best serve their students.

Most teachers also participated in lesson study (Lewis et al., 2006), in which they co-planned a lesson and assessments, observed one teacher teach the lesson, and then analyzed student work to inform improvements to their instruction for the next round. Thus, learning for teachers was iterative and constructive, in that they experienced particular pedagogies as learners, tried them out in their classrooms, observed student learning, engaged in discussion regarding adaptations to their local context, and then returned to workshops to experience additional professional learning. SLP also supported district capacity building through 3–4 hour meetings three times per year with teachers and district and site administrators. Ninety-nine teachers were involved in at least one PD session during the 2020–2021 school year.

Due to the ongoing COVID-19 pandemic and concerns for the health and safety of school communities during the 2020–2021 school year, all school districts included in this study engaged in fully remote instruction for the majority of the school year. Some districts returned to partial in-person instruction for the last 2 months of the school year, but the bulk of instruction during the period of this study was conducted via online platforms such as Zoom or Google Meet. Because SLP teachers reported limited district guidance in the shift to distance learning, the SLP team immediately shifted gears to recreate the central components of the PD in the virtual learning environment and respond to teachers' needs in the midst of a fluid and constantly changing environment. Virtual PD sessions incorporated inquiry-based learning, small group discussions in breakout rooms, interactive slide decks that facilitated collaboration, and demonstrations of a wide range of digital platforms and tools for teaching. SLP hosted weekly informal sessions on Zoom to share information and technology as well as offering a space for teachers to discuss challenges, share resources, and support each other during the transition to virtual learning.

3.2.2 | Organizational setting

Before the pandemic, the sampled teachers' districts and school sites were fairly similar in their approaches to science education. Across districts, science was de-emphasized compared to math and language arts, due largely to the pressures of accountability and a focus on basic literacy in California and the United States as a whole (Hayes & Trexler, 2016; Dorph, et al., 2011). In addition, no partner districts had approved a curriculum specific to NGSS, despite its adoption 12 years earlier. Science was on the "back burner," and some principals even told teachers not to teach science. However, science was also sometimes a space of autonomy for teachers because of the lack of emphasis in accountability reporting requirements.

This similarity across districts and schools changed during the pandemic. Although all districts continued to pay very little attention to science at the elementary level, the degree of autonomy regarding class time, use of materials, and pedagogical approach held by teachers became greatly differentiated. Some districts dictated specific time for math and language arts, and required teachers to follow pacing guides. Others merely specified the amount of synchronous zoom time per day, and allowed teachers nearly total freedom in their curriculum. Likewise, the approach to materials differed, with some districts and schools supporting teachers in sending materials home, and others forbidding it. These contextual differences will be unpacked further in the findings.

3.3 | Sample and data collection

To answer our research questions, we asked 3rd–5th grade teachers that were participating in SLP to complete three related surveys: instructional practices alignment (Hayes et al., 2019), equity self-efficacy (Ritter et al., 2001), and reform conditions (Settlage et al., 2015; Short & Johnson, 1994). In 2021, 54 teachers completed the survey, but due to missing data on key variables our quantitative models range in size from 48 teachers to 51 teachers. We also asked all participating teachers to voluntarily take part in an interview (described below). We selected a sample of 19 teachers out of the total who interviewed ($N = 29$) based on survey completion and distribution across districts to capture the greatest variance in organizational context. The demographics of surveyed and interviewed teachers are shown in Table 1. Table 2 provides information regarding the variables measured in the three surveys. In the sections below, we detail how the scales were created or adapted from existing measures, and evidence of their validity and reliability.

TABLE 1 Sample descriptives.

	Qualitative sample	Quantitative sample
White and not Hispanic	42%	41%
Person of color	47%	37%
Female	90%	82%
Master's or PhD	47%	39%
Third grade	53%	41%
Fourth grade	11%	30%
Fifth grade	37%	26%
Average years teaching experience (range)	17 (4–30 years)	15 (1–31 years)
Average science PD hours over 3 years (range)	13 (0–60 h)	8 (0–60 h)
Average hours of SLP PD (range)	142 (48–229 h)	96 (19–229 h)
Total *N*	19	54

Note: Percentages do not sum to 100 due to missing demographic information for some teachers. All percentages were rounded up or down to the nearest decimal. Person of color included any teacher who identified as Hispanic/Latino, American Indian/Alaska Native, Asian, Black/African American, Native Hawaiian/Pacific Islander, or multiracial. The quantitative sample consists of teachers that are also in the qualitative sample.

Abbreviation: PD, professional development.

Although the survey sample size is relatively small for quantitative analyzes, such small sample sizes can still yield meaningful results, especially when the effects are significant and the model is justified theoretically (Kowalksi et al., 2020; Wallace, 2009). Further, the qualitative strand attenuates some of these limitations by providing a nuanced understanding of teachers' sense-making of their implementation of equitable, reform-based science practices in relation to their organizational contexts. Together, the mixed methods approach supports a set of holistic insights that purely qualitative or even large-scale quantitative approaches would not have been able to capture. That said, future research is needed to examine whether the quantitative relationships between PD, teachers' equity self-efficacy, and their instruction identified in this study can be replicated with larger samples.

3.3.1 | Instructional practice

To measure teachers' reported instructional practice, we used a survey called the instructional practices alignment scale (Hayes et al., 2019; adapted from Schultz, 2002). Based on work by Schultz (2002), this scale uses overlapping circles to demonstrate teachers' perception of the relationship between a particular pedagogical principle, their beliefs, and their practices. The pedagogical principles are listed in Table 3. Teachers are asked to choose which set of overlapping circles (no overlap to complete overlap) best represents alignment between their own beliefs and the pedagogical principle. Directly following, they are asked to indicate which set of circles represents the overlap between their instructional practices and the pedagogical principle. In our prior work, we have found this measure to be a helpful depiction of the alignment between teacher instructional practices and the pedagogical principles underlying PD, as teachers reflect on the degree to which they are able to align their instructional practices with both the PD and their own pedagogical principles. For both the original instrument (Hayes et al., 2019), and the current version used for SLP, content validity was established through literature review and expert review. Face

TABLE 2 Survey constructs: Definitions, literature sources, example item, and construct reliability.

Construct (Cronbach's alpha)	Definition	Stem and options	Example item (#items)
PD predictor			
PD hours	Hours of participation in SLP PD up to the point of the survey		Measured through participant tracking
Main outcome			
Instructional practices alignment ($\alpha = 0.863$)	Alignment between equitable reform-based pedagogical principles and teacher's instructional practice (Hayes et al., 2019)	Which figure best represents the overlap between your current PRACTICES and the above statement?	See Table 3
Mediating variable			
Equity self-efficacy ($\alpha = 0.843$)	Teachers' belief in their ability to meet the science learning needs of marginalized children (Ritter et al., 2001), specifically that teacher actions will lead to particular outcomes for students (outcome expectancy)	Please indicate the degree to which you agree or disagree with each statement below: Strongly agree to strongly disagree	I have the ability to help children from low socioeconomic backgrounds be successful in science. (5)
Organizational conditions (predictors) (Settlage et al., 2015; Short & Johnson, 1994).			
Cultural dimension			
Impact on other teachers ($\alpha = 0.729$)	The degree of influence teachers believe they have on other teachers at their site in terms of science education	Rate the degree to which you believe these statements are true: Not at all true to very true	I believe I have an impact on the way science instruction happens at my school. (3)
Principal support ($\alpha = 0.938$)	The degree to which the teacher perceives the principal supports science education		The principal actively supports finding time for science instruction. (6)
Autonomy in instruction ($\alpha = 0.924$)	Degree of choice in both pedagogy and curriculum, including selecting teaching techniques and addressing student needs	How much choice do you have over each of the following aspects? No choice to strong choice	Selecting science teaching techniques (3)
Autonomy in instructional time ($\alpha = 0.872$)	Degree of choice in determining the designation of class time		The way class time is divided (2)
Shared leadership ($\alpha = 0.717$)	The degree to which teachers have input on organizational structures such as science curriculum, time allocation, and resource allocation	How much input do you have regarding of the following aspects? No input to high input	Selecting science curriculum (5)

(Continues)

TABLE 2 (Continued)

Construct (Cronbach's alpha)	Definition	Stem and options	Example item (#items)
Social dimension			
Collaboration focus ($\alpha = 0.869$)	Time spent collaborating with other teachers with the focus on science teaching and learning	During the past month how often did you engage in the following activities with other teachers? Never to more than 8 times	Work together to develop the goals or objectives for science instruction (3)
Collaborative culture ($\alpha = 0.863$)	A culture in which sharing ideas and feedback from colleagues supports improvements in teaching	Rate the degree to which you believe these statements are true: Not at all true to very true	Feedback from a colleague at my school has improved my science teaching (3)
Trust ($\alpha = 0.854$)	A climate of trust and support amongst teachers at the site		Teachers at my school extend help to their colleagues (4)
Structural dimension			
Science teaching resources ($\alpha = 0.779$)	The degree to which supportive structural and material resources were present and high quality	Rate the extent to which each resource, as it exists in your district or site today, supports science instruction: This resource is absent or low quality to this resource is present and high quality	Curriculum (4)
Policy dimension			
Policy: equitable science initiatives ($\alpha = 0.632$)	Teachers' perception of the degree to which district and state initiatives support them in implementing equitable science instruction.	Rate the extent to which each site, district, or state policy supports or inhibits equitable science instruction: Inhibits equitable science instruction to supports equitable science instruction	Pacing guides (3)
Policy: equitable class time ($\alpha = 0.494$)	Teachers' perception of the degree to which class time policies support equitable science instruction.		Pullouts for ELL or other interventions (3)
Policy alignment ($\alpha = 0.891$)	The degree to which an equitable reform-based approach to science education/PD activities were consistent with policies at the site, district, and state level (Garet et al., 1999)	From my perspective, the PD activities were:	Consistent with my district's policies for teaching and learning (3)

Abbreviation: PD, professional development.

validity was established through review of the items by teachers, who were asked to make adjustments to wording and discuss the understandability of the overlapping circles (25 and 5 teachers, respectively, in the original and current version; Desimone & Le Floch, 2004). Exploratory factor analysis (EFA) revealed a bifurcation along the lines of belief alignment ($\alpha = 0.885$) and practice alignment ($\alpha = 0.863$). For this study, we are using solely the practice alignment items, which were averaged because of the high alpha and consistently high (CFA factor loading: 0.736–0.836).

TABLE 3 Pedagogical principle statements from the practices alignment scale.

Principle 1	The role of teachers should shift from being the primary source of knowledge to being a facilitator of learning. This requires that students consistently engage in investigating science phenomena.
Principle 2	Scientific literacy involves students in exploring, modeling, and explaining scientific phenomena. Student opportunities for engaging in discourse and other forms of communication are pivotal to supporting scientific literacy.
Principle 3	During science instruction, teachers should use the cultural experiences of English Language Learners to build connections to home environments and increase relevance. When this happens, students learn to value their cultural identities and develop their identities as science learners.
Principle 4	Assessment and examination of student work needs to shift from solely evaluating what students know to thinking about how students understand science.

3.3.2 | Equity self-efficacy (adapted from Beliefs about Equitable Science Teaching; SEBEST questionnaire)

This measure was based on Bandura's (1997) concept of self-efficacy, modified by Ritter et al. (2001) to focus on equitable science teaching practices. For this study, we use only items within the outcome expectancy factor, selecting items most closely related to SLP PD and the teaching context (e.g., we selected items focused on race and multilingual students rather than gender, for example, "I am able to meet the learning needs of children of color when I teach science"). Because these are internal psychological constructs that reflect one's own beliefs, scholars have argued that self-report is a conceptually appropriate, reliable and valid measurement approach (Appleton et al, 2008; McDonald, 2008). We adapted reverse score items to be positive, and reworded items to be present rather than future tense for our in-service teachers. As with all of the measures within this study, the items were reviewed by teachers with wording suggestions and discussion of meaning. Cronbach's alpha for the equity self-efficacy ratings was 0.843, demonstrating high internal reliability.

3.3.3 | Perceptions of organizational conditions

We define organizational conditions for reform as aspects of the organization shown to influence teacher learning, teacher self-efficacy in relation to equity, and teacher enactment of reformed instructional practices (Settlage et al., 2015; Short & Johnson, 1994). We used a framework of instructional capacity (Hayes et al., 2020) to specify organizational conditions across the cultural, social, structural, and policy dimensions. Through a review of the literature (above), we then determined what organizational conditions across these dimensions specifically influence equitable, reform-based science education at the elementary level. We examined existing instruments that measured such resources and conditions. The two most closely related instruments were Settlage et al.'s (2015) School Science Infrastructure Scale and Short and colleagues' work on teacher empowerment, which took place between 1992 and 2006 (Short & Johnson, 1994; Pearson & Moomaw, 2006).

We adapted and combined items to form coherent constructs in relationship to our research questions, the SLP context, and our framework (Table 2). The resulting items were subjected to a validation process through both the literature and participant interviews. A group of 20 teachers examined the items and were asked to comment on the extent to which each construct measured something important in their experiences of science education, the items that best represented that construct, and any necessary wording changes. Importantly, the constructs represent teacher perceptions of the organizational environment, not an objective measure of the state of each condition. Yet, perceptions may play an outsized role in how teachers take up and implement reform-based instructional practices (Hayes et al., 2023; Stollman et al., 2020); thus the measure has potential for supporting understanding of the complex interactions that shape teacher implementation as they learn in PD.

Because of the adaptations made to existing scales, we used a maximum likelihood EFA to establish the underlying factor structure of the data (Matsunaga, 2010). Cases were excluded pairwise. Our cutoff value for factor loading was 0.40. We allowed the number of factors to emerge based on eigenvalues greater than one. We conducted a CFA using M*plus8*. Goodness of fit was determined using the criteria from Hu and Bentler (1999); for the comparative fit index (CFI) and the Tucker–Lewis index (TLI), values above 0.90 were used as an indication of adequate fit; for the root-mean-square error of approximation (RMSEA), 0.06 or below indicates adequate fit; and for the standardized root-mean-square residual (SRMR), 0.08 or below indicates adequate fit. Model fit indicated acceptable fit [CFI = 0.863; TLI = 0.843; RMSEA = 0.066; SRMR = 0.075]. The standardized factor loadings were high, ranging from 0.514 to 0.987. Cronbach's alpha (computed using SPSS) for each factor was high, indicating high internal consistency ($\alpha = 0.717–0.938$; Table 2), with the exception of "Policy: Equitable Class Time" ($\alpha = 0.494$).

3.3.4 | Qualitative data: Teacher interviews

Teachers who were actively engaged in SLP during the 2021–2022 school year were invited to participate in a 45–60 min semi-structured interview (Roulston, 2010) to better understand their perspectives on teaching science during the pandemic and the shift to remote instruction. Interview questions focused on teachers' experiences with remote instruction, strategies for engaging students in equitable reform-based instructional practices, their experiences with SLP during this period, and their perception of barriers and supports for science education in the organizational environment. All interviews were conducted using Zoom, recorded with permission, and transcribed verbatim.

3.4 | Analyses

3.4.1 | Quantitative data analysis

M*plus*8 (Muthén & Muthén, 2012–2019) was used to conduct the quantitative analyzes. We used the maximum likelihood estimation with robust standard errors (MLR) estimator because it handles missing data and smaller sample sizes. To answer research questions 1 and 2 we tested multiple mediation models using measured path analyzes. In research question 1, we were specifically interested in whether participation in PD directly predicted instructional practices, and whether participation in PD indirectly predicted instructional practices through teachers' equity self-efficacy (i.e., mediation pathway). We thus examined a baseline mediation model that excluded organizational variables.

For research question 2, we first conducted correlations to determine variables that were appropriate to include in the mediation model (i.e., organizational variables that significantly correlated with our outcome of interest, instructional practices alignment). Following correlations, we tested whether the three statistically significant organizational variables predicted instructional practices alignment either directly or indirectly through a mediated path via equity self-efficacy. To do this we added each organizational variable individually to the baseline mediation model for a total of three separate models. We engaged in this stepwise modeling process to avoid model overspecification, that is, to simplify models and reduce the number of variables in each model. Our final model included all three organization variables to see which effects would remain when controlling for the other two variables. We report the R2 values for the outcome variables in the final model, providing evidence of how much variance in the outcome (i.e., instructional practices and equity self-efficacy) is explained by the predictors.

3.4.2 | Qualitative data analysis

Interview data was analyzed using a set of a priori codes with the intention of explaining the direction and magnitude of relationships in the quantitative model (Creswell & Plano Clark, 2018; Saldaña, 2009). Based on the final quantitative model, the research team focused on the relationship between PD, teachers' equity self-efficacy, and instructional practices alignment, along with the two organizational constructs that were statistically significant predictors: (1) autonomy in instruction, and (2) impact on other teachers (see construct definitions in Table 2). For the purpose of coding, we defined autonomy as teachers' perception of their degree of choice in overall classroom practice, as mediated by organizational norms and structures. This definition includes pedagogies, instructional materials, and division of classroom time (e.g., how much time to spend on science) (Pearson & Moomaw, 2006; Short & Johnson, 1994). We defined impact as teachers' perceptions regarding their degree of influence on other teachers' classroom practice, as well as influence on site or district decisions (Leithwood & Mascall, 2008; Short & Johnson, 1994). Transcripts were coded using Dedoose qualitative coding software to better understand the ways that autonomy in instruction and teachers' impact interacted with their instructional practices and equity self-efficacy beliefs. After initial coding was completed and discussed, two researchers reviewed the full transcripts of each teacher and wrote a memo describing how each teacher talked about the PD, their instructional autonomy a, sense of impact, equity self-efficacy beliefs, and their science instructional practices across the entire interview, and the relationship between these constructs. The goal of this second phase of analysis was to capture a fuller picture of how teachers were thinking about these concepts in relationship to each other, and whether or not the interview data was aligned with the results of the quantitative model. The final memoing process resulted in four categories of teachers: (1) Those whose experiences support the relationships demonstrated in the quantitative model, including through consistently positive experiences (high instructional autonomy and impact, high equity self-efficacy, and high instructional practices alignment) or through consistently negative experiences (low instructional autonomy, impact, equity self-efficacy, and alignment); and (2) Those whose experiences problematize the quantitative model, including (a) teachers who could not make use of their high instructional autonomy and (b) teachers who resisted low instructional autonomy.

In the discussion, the quantitative results and qualitative findings were brought together to explain the relationships between organizational conditions, teacher equity self-efficacy, and their aligned instructional practices in the context of the PD (Creswell & Plano Clark, 2018). Particularly, we noted areas of the qualitative findings that supported, contradicted, or provided a more nuanced picture of the quantitative relationships identified across the mediation models.

4 | RESULTS

4.1 | Quantitative results (RQ 1, 2)

For RQ1, we examined whether equity self-efficacy mediated the relationship between participation in PD and instructional practices. In our fully saturated baseline model we found that teachers' equity self-efficacy fully mediated the relationship between participation in PD and instructional practices [$\chi^2 = 26.508$, $p < 0.001$; RMSEA = 0.00; CFI = 1.00, SRMR = 0.00]. Because all path models reported in the quantitative results estimate the relationship among observed variables and are thus just-identified, we have perfect model fit; therefore, goodness-of-fit are not listed in subsequent results (Kline, 2012). The baseline model demonstrates that (without accounting for the influence of organizational conditions) intensity of participation in the PD directly predicted equity self-efficacy ($\beta = 0.250$, $p = 0.031$), equity-self-efficacy directly predicted instructional practices ($\beta = 0.566$, $p < 0.001$), and participation in PD significantly indirectly predicted instructional practices through equity

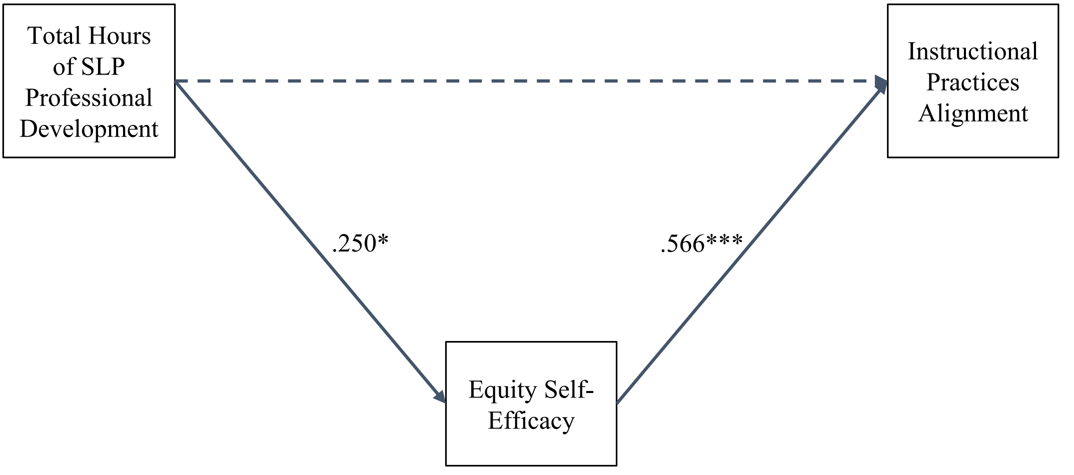

FIGURE 2 Baseline model for RQ1. Coefficients are standardized betas and represent direct effects. Dashed lines represent direct paths that were not significant. ***$p < 0.001$, **$p < 0.01$, *$p < 0.05$.

self-efficacy ($\beta = 0.141$, $p = 0.041$) (Figure 2 and Table 5). Thus, teachers' equity self-efficacy is an underlying mechanism by which participation in PD predicts instructional practices.

For RQ2, we tested the predictive role of different organizational conditions on equity self-efficacy and instructional practices alignment in the baseline mediation model (that includes PD as a predictor of equity self-efficacy and instructional practices alignment). We first examined correlations to determine which of 11 organizational condition variables were appropriate to include in the mediation models (see Table 4). The only organizational variables that were significantly correlated with both equity self-efficacy and instructional practices alignment were in the cultural dimension: *impact on other teachers* ($r = 0.463$, $p < 0.001$; $r = 0.388$, $p = 0.006$, respectively), *instructional autonomy* ($r = 0.583$, $p < 0.001$; $r = 0.330$, $p = 0.019$, respectively), and in the policy dimension: *policy alignment* ($r = 0.295$, $p = 0.036$; $r = 0.287$, $p = 0.039$, respectively).

These three organizational variables were then added individually to our baseline model to examine whether they predicted equity self-efficacy, and if they predicted instructional practices directly or indirectly through a mediated path via equity self-efficacy. In our three individual fully saturated models [$\chi^2 = 30.447$–62.405, $p < 0.001$], we found that both impact on other teachers ($\beta = 0.200$, $p = 0.004$) and autonomy in instructional practice ($\beta = 0.428$, $p < 0.001$) significantly indirectly predicted instructional practices alignment as mediated by equity self-efficacy (Table 5). Policy alignment only had a marginally significant indirect effect on instructional practices alignment via equity self-efficacy ($\beta = 0.131$, $p = 0.051$). These relationships were fully mediated, that is, there was no significant direct relationship between the specific organizational variable and instructional practices alignment.

Our final model ($N = 48$) included all three organization variables together to see which effects would remain when accounting for the other organizational variables (Figure 3). In the final model, autonomy in instructional practice had the strongest indirect predictive relationship of reform-aligned science instruction compared to the other organizational variables (indirect $\beta = 0.329$, $p < 0.001$). Impact on other teachers marginally significantly indirectly predicted instructional practices alignment through equity self-efficacy ($\beta = 0.130$, $p = 0.055$). Policy alignment was not statistically significant in the final model ($\beta = 0.072$, $p = 0.195$). In terms of effect size, the R^2 value for instructional practices alignment was 0.405 ($p = 0.001$) and was 0.546 ($p < 0.001$) for equity self-efficacy, indicating that the model accounted for 40.5% of the variance in instructional practices alignment and 54.6% of the variance in equity self-efficacy. The final model thus explains a substantial portion of the variance in our dependent variables of interest. This model also had excellent fit [$\chi^2 = 72.354$, $p < 0.001$].

TABLE 4 Correlations between all variables.

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
PD hours	1.00														
Instructional practices alignment	0.20	1.00													
Equity self-efficacy	0.25	0.55***	1.00												
Impact on other teachers	0.16	0.38**	0.46***	1.00											
Principal support	−0.30*	0.15	0.18	0.31*	1.00										
Autonomy in instruction	0.19	0.33*	0.58***	0.18	−0.05	1.00									
Autonomy in class time	0.09	0.00	0.05	0.09	−0.02	0.51***	1.00								
Shared leadership	0.15	−0.04	0.10	0.22	0.36*	0.28*	0.53***	1.00							
Collaboration focus	0.04	0.14	−0.16	0.01	0.26	0.11	0.24	0.31*	1.00						
Collaboration culture	−0.06	−0.20	−0.06	0.07	0.21	0.11	0.26	0.24	0.41**	1.00					
Trust	0.06	0.09	0.48***	0.46***	0.32*	0.36**	0.17	0.37**	0.07	0.20	1.00				
Science Teaching Resources	0.00	−0.08	−0.05	−0.07	0.28	0.13	0.10	0.35*	0.22	0.17	0.18	1.00			
Policy: Equitable science initiatives	−0.24	−0.15	−0.06	0.13	0.52***	−0.06	−0.03	0.43**	0.19	0.05	0.36*	0.45**	1.00		
Policy alignment	0.22	0.29*	0.30*	0.33*	0.36*	0.12	−0.11	0.27	0.21	0.26	0.47***	0.38**	0.32*	1.00	
Policy: Equitable class time	−0.15	−0.05	−0.08	0.04	0.31*	−0.11	−0.10	0.20	0.07	0.02	0.26	0.11	0.63**	0.30*	1.00
Mean	95.48	3.11	3.89	3.48	3.00	4.25	3.54	2.82	1.57	3.47	3.86	2.37	2.66	3.96	2.20
SD	64.26	0.75	0.63	0.66	0.82	0.65	1.02	0.90	0.66	1.04	0.63	1.10	0.86	0.75	0.71

Note: $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.

Abbreviation: PD, professional development.

TABLE 5 Standardized mediation models for each organizational variable (standard error in parenthesis).

	Total effects of predictors		Indirect effects of predictors to DV (via mediator)		Direct effects of predictors to mediator and to DV				Direct effect of mediator to DV
Predictors	Total effect PD	Total effect Org variable	PD to practices alignment	Org variable to practices alignment	PD to SE equity	Org variable to SE equity	PD to practices alignment	Org variable to practices alignment	SE equity to practices alignment
Hours of PD (*N* = 51)	0.200 (0.144)		0.141* (0.069)		0.250* (0.116)		0.059 (0.109)		0.566*** (0.091)
Impact (*N* = 48)	0.130 (0.143)	0.386*** (0.117)	0.089 (0.060)	0.200** (0.069)	0.176 (0.110)	0.393*** (0.099)	0.041 (0.109)	0.186 (0.121)	0.508*** (0.102)
Autonomy in instruction (*N* = 49)	0.134 (0.135)	0.306* (0.135)	0.090 (0.070)	0.428*** (0.102)	0.135 (0.100)	0.644*** (0.083)	0.044 (0.113)	−0.122 (0.149)	0.665*** (0.130)
Align (*N* = 51)	0.136 (0.149)	0.255[a] (.142)	0.100 (0.065)	0.131[a] (0.067)	0.187 (0.115)	0.243[a] (0.130)	0.035 (0.116)	0.124 (0.113)	0.536*** (0.094)

Note: $^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$.

Abbreviation: PD, professional development.

[a]Marginal effect ($p = 0.05$–0.07).

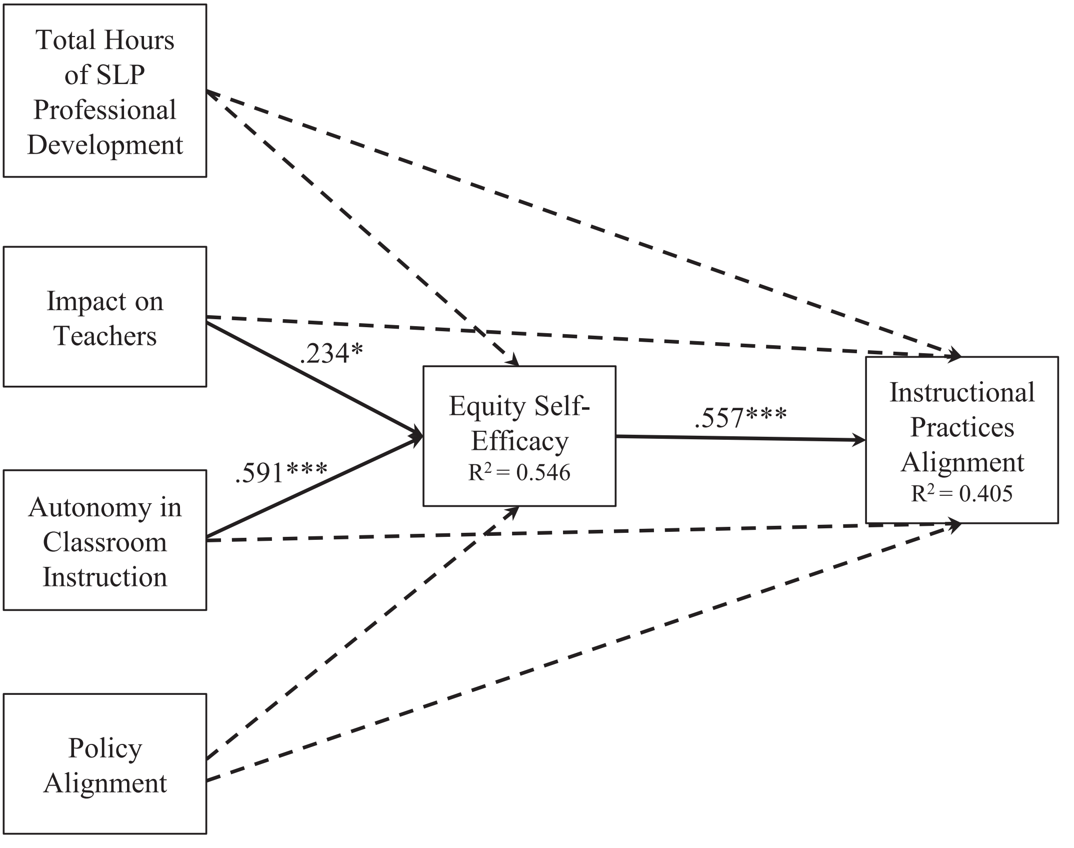

FIGURE 3 Final model (RQ2). Coefficients are standardized betas and represent direct effects. Dashed lines represent direct paths that were not significant. ***$p < 0.001$, **$p < 0.01$, *$p < 0.05$.

4.2 | Qualitative findings (RQ3)

Here we present findings from teacher interviews that contextualize and explain the relationships identified in the quantitative models (RQ3). First, we present findings for teachers whose interviews largely support the overall relationships depicted in the quantitative results, while simultaneously illustrating nuances in directionality and substance of these relationships. We showcase teachers who report all relatively high or all relatively low equity self-efficacy, reform-aligned science instruction, and supportive organizational conditions in relation to the PD. Second, we present findings from teachers whose interview data problematizes the relationships found in the quantitative models, underscoring more complex relationships that don't follow a linear trend. For each, we highlight an example teacher as a way of providing a rich description of these relationships. Of note, in some instances in the interview data there was overlap between domain-general self-efficacy and equity self-efficacy.

4.2.1 | Cases that largely support the pathways indicated in quantitative results

Eight of the 19 interviewed teachers discussed their instructional practices, self-efficacy, autonomy, impact, and PD in ways that supported the quantitative findings in terms of significant, positive pathways between all five constructs. That is, in multiple excerpts across their interviews they brought up specific ways in which two or more of the main constructs interacted in positive ways related to higher instructional practices alignment. An additional two teachers discussed positive relationships between instructional autonomy, self-efficacy, and their instructional practices, but felt they had a low impact at the organizational level. While the illustrations provided here primarily support the quantitative findings, each presented case also demonstrates more complex aspects of the relationships in terms of nature and directionality, particularly in terms of the importance of SLP PD.

Lydia fit this pattern well. She was in her second year of PD, and was a committed participant. Across her interview Lydia indicated a sense of autonomy regarding both her freedom to teach science (autonomy in instructional time) and her ability to resource her science teaching through technology and materials (autonomy in curricular materials). The lack of constraints, combined with her existing equity self-efficacy and what she learned in the PD, allowed her to teach aligned science during her weekly synchronous zoom-based distance-learning time. She described her overall situation as follows: “We did a lot of hands-on science. I did [materials] drop offs every 2 weeks for the whole year.”

She later described a particular strategy:

> We used a Jamboard [SLP strategy]…Where they would have a slide for, “What do I know?” Or, “…What are we learning?” One thing that was great was that I was able to set up the Jamboards per breakout room… The most kids I ever had was 30 kids, so I would have sometimes 15 breakout rooms, because I wanted them to work in partners.

These quotes showcase a number of areas of autonomy that supported her in teaching aligned science. (1) She had permission to disseminate science materials to students’ homes, which allowed her to teach a variety of inquiry-based science lessons; (2) she was able to select (and obtain) technological tools that allowed her to facilitate student sensemaking around science; and (3) she could use breakout rooms, which allowed for student discourse. These areas of autonomy were common across the eight teachers that exhibited this pattern, providing opportunities for more and better aligned science during the pandemic. These patterns directly support quantitative findings.

However, in Lydia's perception, as for most of the teachers, her science teaching was supported by participation in the PD, where she obtained the tools and strategies she discussed such as science teaching approaches for a distance format as well as the technological tools themselves. When asked what supported her change in instructional practice over the year, Lydia said,

> Feeling supported by [PD facilitators] to go and do more…I think [before SLP] when we taught science, we took out the science book, we read the chapter, we answered the questions and then we do an activity. [Now] starting with a phenomenon or something that's engaging and interesting for the kids and then taking that where it goes…

This differs from the results of the final quantitative model, which indicated a statistically insignificant relationship between PD and instructional practices alignment.

In addition, across most of Lydia's comments, her instructional autonomy led directly to her ability to implement aligned instructional practices without clear mediation by equity self-efficacy. For example, after talking about being supported by the PD (above), Lydia talked about being more comfortable following the students’ lead, indicating higher self-efficacy in implementing equitable reform-based instructional practices:

> Instead of, I have a plan and an idea of where I want it to go, the kids would sometimes take it somewhere different. And then I would have to be like, “Okay, we're going to go down here. And then we're going to turn this way so we can come back towards my goal.” I don't think I would've done that [before SLP] when I needed to get through the content.

Lydia's equity self-efficacy appeared to be constructed recursively through trying SLP instructional practices and receiving support in the PD. Without the PD, she would not have learned the instructional strategies that supported her science teaching during the pandemic. Without instructional autonomy, she could not have implemented them. Without self-efficacy, she may not have tried the new strategies. Yet trying out the strategies and reflection in the PD also reinforced her self-efficacy. This was also a common pattern in this group of interviewed teachers. In the following quote, Lydia talks with confidence about how she supported her three English language learners (emic term) in science.

> The strategy that I used for getting my English learners to expand their thinking was first, they would work in a partner or breakout room. They would do something like a Jamboard or a Padlet. Then they would share out their ideas in the whole group…I don't see that this would've been possible if … One, they didn't have materials in the hands. Two, if we didn't have the support for being taught how to use Flipgrid and how to use Jamboard and how to use Padlet.

Because she was able to use whatever technology she wanted as well as sending materials home, she was able to develop greater self-efficacy in using particular tools, supported by the PD. This in turn allowed her to support her English language learners to make sense of the science.

Lydia also talked about having impact, but in a manner relatively disconnected from equity self-efficacy and instructional practice, similar to many of the teachers in this category. Here Lydia describes how she was working with other teacher leaders to get the district to support material dissemination: “so with our science kit committee and through SLP we are making progress in getting the district to get on board with this idea of hands-on materials, students having conversations.”

Another set of teachers illustrated the quantitative relationships by showcasing what it looked like when the focal organizational conditions (impact, autonomy) were absent and how that absence related to teachers’ low equity self-efficacy and misalignment in instructional practices (3 of the 19 interviewed teachers). These teachers talked about constraints in their organizational environment (low autonomy), such as the low number of hours they could be on zoom, whether they could disseminate science materials, and the focus of district and state testing on ELA and math.

Kayla is an example of a teacher whose perceived lack of autonomy for instruction negatively interacted with her equity self-efficacy in supporting diverse students in science. She was a teacher in a bilingual Spanish-English classroom. Through SLP, Kayla gained resources and lesson plans to use in her remote classroom, noting “I have been able to incorporate a lot of the practices and the activities that I'm learning through the program with my students online…if it weren't for SLP, I wouldn't have tried Flipgrid”

Yet, despite her enthusiasm and knowledge gained in SLP, Kayla struggled to prioritize science instruction in the context of her classroom and district mandates, where pressure to prioritize language arts and math instruction left her feeling like she was doing a “disservice” to students if she wasn't preparing them for specific benchmarks (lack of autonomy in instructional time due to organizational norms and structures). Kayla ran into challenges with the structure of her virtual classroom, getting materials out to students, and supporting the needs of her bilingual students. More than anything, Kayla did not feel a high degree of autonomy with regard to her teaching schedule and how she approaches science instruction. As she stated,

> I find myself a lot of times saying, I want to do this [science activity], but it's going to take two hours. Then they have this test for the district benchmark, or they have this test for the state. So I find myself sometimes questioning whether I'm doing them a disservice if I don't focus my two hours on preparing them for that fractions test that I know is coming up… instead of engaging them in these learning experiences of science.

With limited synchronous time with her students during remote learning, Kayla felt the tension between wanting to meet her students' needs in science and organizational constraints, questioning her ability to best support her students' learning (lower equity self-efficacy) and reducing her instructional practice alignment (not teaching science).

Kayla also perceived organizational constraints (lack of autonomy) because of her student population. With 16 English language learners in her class, she was mandated to teach 30 min of English Language Development Time per day, cutting into her instructional time. She received push-back from parents regarding this, stating, "I also had some complaints about, why are those 16 receiving more instruction than the rest?" Kayla struggled to offer support for her students' learning needs within the constraints of the district's mandated online class structure and miscommunication with parents. While most parents eventually understood her reasoning for shifting the structure of online class time, this pushback and lack of autonomy eroded her equity self-efficacy and her ability to focus on science instruction.

Like many of our teachers, Kayla felt like she had a small, localized impact in terms of supporting her partner teacher as she learned new strategies for teaching science, stating, "She's very much on board… Sometimes I do part A and she does part B [of the science lesson] so that we divide and conquer the tasks…" Yet, while Kayla felt a sense of impact in being able to mentor her new partner teacher in science instruction, her other comments indicate that she was still grappling with overall impact and feeling ineffective in teaching science to her bilingual students.

4.2.2 | Qualitative findings that problematize quantitative results

Can't make use of high autonomy: Four of the interviewed teachers indicated that they had high levels of instructional autonomy, and yet they still struggled to implement reform-based science instruction. Primarily, this was due to existing challenges with equity self-efficacy, as well as other beliefs regarding pedagogy. As an example, Maxine, who participated in SLP for 2 years before the shift to remote learning, felt no constraints from the district regarding when and how she could teach science. Overall, Maxine felt a high degree of autonomy related to sending materials home for science, using a variety of technology tools such as Padlet, and integrating it into her synchronous sessions as she saw fit.

To teach science, she primarily used a video-based science program her district had purchased for elementary teachers. Of the new materials she stated, "For what we're doing with distance learning, it's good because it has the videos, it has an activity…it has discussion questions, and so on." She recognized this approach did not always support student learning, and was trying to overlay some of the tools and strategies from the PD. As she described,

> But SLP is the reason why I'm changing those strategies, because it works, because I see the kids doing better, engaging more. And they like the technology piece that you guys have been adding in is… It works for them. It's a little struggle for me, but it works for them.

Maxine valued the PD and was excited by how her students warmed to the new strategies and technologies, but she still struggled with her confidence in teaching science and using distance learning tools.

Maxine struggled with her equity self-efficacy and instructional practices alignment in other ways as well. She exhibited a tension between trying to incorporate SLP student discourse into her practice and her proclivity toward teacher-centered approaches. She said,

> They're young and they're not used to this kind of inquiry, so I find that I want to explain everything to them… So just trying to focus them in and train them to talk to each other more and to stay on topic. So that has been challenging for me. And also letting go of my part in it, what I think is my part, explaining everything to them.

This quote showcases Maxine's lower self-efficacy in teaching equitable, reform-based science instruction based on her perceptions about the role of students and teacher.

This struggle to incorporate student-led discourse was further complicated by Maxine's belief that her students preferred that she provide a clear explanation instead of creating opportunities for student-led inquiry. As she put it, "I find that, especially with my [multilingual] students or my resource students, that they want me to do it for them. They want me to tell them everything."

Additionally, Maxine was concerned that students' discussions of scientific concepts would veer into misconceptions that she would then need to redirect and explain.

> This past week I did an activity with them that we had done during that [SLP]… We did a Padlet and we did a diagram. And we read Newton, so they learned some vocabulary…Then at the end I showed them the [video] where it explains what happens, but they went some other direction with it… I have to talk to them on Monday and clear up that direction.

In this quote, Maxine described trying out SLP activities, along with technological tools she learned in the PD, but she was focused on vocabulary acquisition rather than conceptual learning, and struggled with how to close the lesson to make sure students "got it."

Overall, Maxine experienced relatively high autonomy in regards to her classroom instruction; she tried implementing science lessons from the PD and experimented with technology to support her students' remote learning. However, her equity self-efficacy and aligned instructional practices was hampered by her existing belief systems about student learning. She felt a tension between the pedagogical principles that undergirded the instructional practices that she was experimenting with and her existing teacher-centered approach and focus on vocabulary acquisition. She worried that without didactically explaining the science to students, they would miss out on learning, and she thought the students themselves needed and wanted information transmission from the teacher. Such tensions showcase relationships among the constructs for some teachers that counter the primary relationships demonstrated in the quantitative model.

Resisting low autonomy: A small subset of the teachers (2 of 19) indicated low instructional autonomy in their interview, but found ways to resist, and spoke of implementing relatively strong reform-aligned instructional practices. Although low in number, these teachers complicate the quantitative findings and provide important insight into the potential role of teacher and PD factors in navigating organizational conditions for science teaching and learning.

For example, Paula's organizational environment was relatively constrained. A mandate from the district office asked teachers to focus solely on math and English language arts (lack of autonomy in instructional time), and her site administrator wanted teachers to push vocabulary acquisition (lack of pedagogical autonomy). Teachers also weren't allowed to send materials home to students unless the entire grade level received the same set of materials. Since Paula's grade level teachers were not interested in organizing materials, she could not send them home (lack of curricular autonomy). Unlike some teachers, Paula was allowed to have breakout rooms on zoom.

Yet, Paula regularly resisted constraints if she felt they were not in the best interest of students, trying to find a workaround to organizational barriers to teach equitable, reform-based science instruction. She described: Even after they have come down and said,

> 'We only want you teaching reading, writing, listening, speaking, and math,' I still teach science and social studies, because I've been teaching long enough to know that we want to teach the whole child.

Sometimes these creative workarounds succeeded, and Paula was able to continue teaching aligned science under the radar. When asked whether her science time increased or decreased, she laughed and said it had increased because of the lack of surveillance.

> The reason I say increased is because I don't have admin walking through my classroom, because I'm here at home. Where [last year] we were doing science two days a week and being told that was too much, [now] we do science every day.

She described how a few years before, the district had put forth a “new vision of cookie-cutter classrooms,” where each grade level room looked like the other. She stated flatly, “That's a bad mentality, but fire me.” She then went on to note, “…because [of the pandemic] our classrooms didn't have to look the same because I'm here. Unless you have a camera on my wall, I'm teaching what I think they need.” These quotes illustrate how Paula's existing equity self-efficacy (ability to support the learning needs of students) supported her aligned science instruction in the face of low autonomy.

Other times, Paula was unable to continue her resistance to organizational constraints. Here Paula described how she tried to get materials for science out to the students sneakily by having the team mom pass it out without her presence. Someone “spilled the beans” and she “got in trouble,” after which she didn't “cheat.”

> I think one of the big barriers is the materials. The materials handout was highly regulated, the grade level was mandated to send out all of the same exact materials… The other teacher in the grade level [was]…not really into science…That extra restraint of your materials bag is going to look exactly like somebody who just teaches reading, writing, listening, speaking, and math is a frustrating situation. I cheated once and I got in trouble. I didn't cheat after that.…My team mom passed that out at a local park with me not present. I got in trouble because somebody spilled the beans.

Even with lack of materials she still tried to find a way to teach aligned science instruction. During a geology lesson on slope, she wanted the students to explore how to protect homes on a steep slope. She said, “Because not everybody had the same kind of materials, I actually had them draw it in Google slides. They would draw a house and then they would draw their idea of how they would construct a model to protect.” She then stated her misgivings, saying, “To me that's a weak model because it's more of a drawing of a model versus a creation of a model.”

Like most teachers, Paula credited SLP PD with supporting her resistance, both in terms of providing technological tools but also a community supportive of aligned, equitable science. She said,

> It's a lifeline. I think especially … at the end of last year, having all those tech hubs and those think tanks where you had a safe place to ask questions and … know that you're not the only person in the world that feels like kids should get some of these things.

Paula experienced low autonomy, but drew on her existing belief structures (including equity self-efficacy) and the PD to resist organizational constraints, continuing to teach reform-based science. This pattern, although only found among two teachers in the qualitative data, demonstrates the non-correlational and complex ways the quantitative variables can manifest in specific cases.

5 | DISCUSSION

Science PD providers often struggle to understand why some teachers take up new instructional practices and others do not. Many studies explore the role of individual teacher characteristics such as science content knowledge and self-efficacy in influencing this uptake (Banilower et al., 2007; Perera et al., 2019). Yet, in most PD studies, organizational conditions are treated as barriers to PD rather than a mechanism of differentiation in teachers' implementation of reform-aligned instruction. There has been little systematic research on which organizational conditions most profoundly influence the translation of PD to practice, making it difficult to address organizational barriers to professional learning (Boylan & Demack, 2018; Kennedy, 2010; Opfer & Pedder, 2011; one exception is Schipper et al., 2020). There is a particularly urgent need to understand the role of organizational conditions in teacher learning of equitable instructional practices because of the need to shift elementary classrooms into spaces where historically marginalized students are able to thrive as learners of science (Bang et al., 2017; Barton & Tan, 2009). Gaining such insight can allow PD providers and researchers to address organizational conditions as part of planning and carrying out PD, facilitating greater teacher change and potentially supporting more equitable learning environments for our diverse students (Heredia, 2020).

5.1 | The relationship between PD, equity self-efficacy, and aligned instructional practices

In addressing research question one, we established a baseline quantitative model, demonstrating that equity self-efficacy acted as a mechanism by which participation in PD predicts reform-aligned instructional practice. Although there is a large literature base establishing the relationship between PD and teachers' self-efficacy (Lowell & McNeill, 2022; Seneviratne et al., 2019), and between teachers' self-efficacy and improved science instruction (Lakshmanan et al., 2011; Perera et al., 2022), to our knowledge the mediating role of self-efficacy between PD and instruction has not been directly examined. This study extends the literature on science PD, teacher self-efficacy, and science instruction by empirically establishing this mediating relationship. Yet, while we are able to contribute a positive relationship to the mixed literature, we caution against overgeneralization. Equity self-efficacy may have a significant relationship to outcomes of interest because of the focus on equity and the particular context of this study, an elementary science equity-focused PD in which a particularly diverse set of teachers worked with diverse students (Settlage et al., 2009). With a growing call for the need to center student discourse and elevate the voices of diverse learners, it will be important for future research to continue examining the role equity self-efficacy has on teachers' equitable instructional practices (Bang et al., 2017; Ritter et al., 2001).

It was unexpected that hours of PD participation became non-significant in our final model (with the inclusion of organizational variables). Here the qualitative aspect of our study did not align with the quantitative findings. Across all sampled interviews, the teachers talked about the PD supporting their science teaching, even if they struggled to implement reform-based instructional practices (of note, although the interview questions asked overall where teachers learned new strategies and gained sources of support, because the interviewer was associated with SLP, teachers may have discussed the PD to a greater extent than other sources of support).

First, teachers noted that SLP offered tools and strategies for teaching science in a distance format. As previous literature has shown, providing teachers with resources and materials that are engaging and appropriate to their classrooms and students is an important component of effective PD (Fore et al., 2015). This support was critical during the initial months of the pandemic when SLP was the only forum to learn how to teach online and practice the various technologies. Second, teachers spoke often of the sense of community they felt in SLP. This was particularly important for teachers whose schools and districts were navigating unprecedented challenges during the pandemic and could not offer organizational stability conducive to teacher self-efficacy and success (Kraft et al., 2021; Reich et al., 2020). Third, teachers felt they were able to have a positive impact on their fellow teachers through sharing the resources and skills they gained through SLP (impact). They were also able to resist lack of instructional autonomy through self-efficacy and instructional strategies honed through the PD. In this way, SLP served as a buffer or support for teachers who were in districts that did not support their autonomy or impact. SLP teachers were doing their best to teach science and use new technologies to support learning during the pandemic and needed external legitimization. The role of PD as a source of legitimacy has been noted as potentially transformative in other studies (Hayes et al., 2019; Heredia, 2020; Zafrani & Yarden, 2022).

Taken together, the qualitative findings indicate a central role of PD in teachers' implementation of reform-aligned science instruction. One possible reason for the statistically non-significant role of PD in the quantitative model is that the PD variable was not self-reported (cumulative hours of participation) while the other variables were aggregated from self-reported survey data using Likert scales.

5.2 | The role of organizational conditions

To understand the role of organizational conditions (research question two), we systematically tested a theoretically grounded set of 11 organizational conditions in relationship to teacher equity self-efficacy and instructional practices. Only two organizational variables retained significance in the final model. Teachers' sense of their *professional impact* and *autonomy in instructional practice* significantly predicted their equity self-efficacy and implementation of equitable, reform-based instructional practices (of note, the variable encapsulating teacher autonomy in determining the division of class time was not significant). Together, the final model explained substantive variance in the dependent variables (40% of instructional practices alignment and 54% of equity self-efficacy). Although the sample size is small, this effect size points to the potential salience of the two significant organizational conditions, which fell within the cultural dimension of the framework of organizational conditions (Hayes et al., 2020). This placement is noteworthy given that much of the money and effort in science education reform is focused on the structural dimension (e.g., curriculum, materials). Yet, a growing body of literature supports the notion that targeting resources to develop aspects of organizational cultur may generate important benefits in terms of supporting teacher change in instructional practice. For example, in addition to autonomy and impact, other studies have pointed to the importance of coherence and trust (Allen & Penuel, 2015; Longhurst et al., 2017).

In the qualitative analysis, 13 of the 19 interviewed teachers spoke about the constructs in ways that supported these relationships. That is, these teachers experienced high instructional autonomy and impact, high equity self-efficacy, and correspondingly high alignment in instructional practices (~10 teachers), or the reverse (3 teachers). Yet 6 of the 19 teachers showcased why and how the relationships in the quantitative model were not stronger. Three of these teachers had relatively high autonomy, but were unable to make use of this freedom to teach aligned science instruction due to issues with their equity self-efficacy or other teacher-centered pedagogical beliefs. Two teachers experienced high organizational constraints (low autonomy), yet nonetheless implemented reform-based science pedagogies, drawing on existing equity self-efficacy and what they learned in the PD to fortify this resistance to organizational barriers.

We define instructional autonomy as teachers' *perceived* degree of choice, afforded by their schooling and broader contextual norms and structures, in selecting teaching techniques and curriculum, and determining how to address student needs and instructional time (Pearson & Moomaw, 2006; Schipper et al., 2020; Short & Johnson, 1994). Although autonomy in class time was not significant in the final quantitative models, in qualitative data there was considerable overlap between autonomy in instruction and class time, so we discuss them together. We conceptualize autonomy as an aspect of organizational culture; it is thus not a measure of teacher autonomy within the PD. A growing literature base shows that a certain degree of instructional autonomy may be necessary for teachers to feel a sense of ownership regarding their implementation of reform-based instructional practices (Davis, 2003; Szelei et al., 2020). Our mixed and qualitative findings build on this literature, suggesting that instructional autonomy allows for the teaching of science and provides the space to try out reform-based instructional practices.

However, such autonomy may be necessary but not sufficient; it may only function as a support for equitable, reform-based instructional practices if combined with sufficient PD and a collaborative learning community, in which a shared vision of student assets and reform practices is developed (Davis, 2003; Lamb et al., 2011; Rivera Maulucci et al., 2015). Our findings support this notion: SLP teachers could not make use of instructional autonomy if their beliefs, self-efficacy, and/or skills were not well-enough aligned with the principles underlying equitable, reform-based pedagogies. We thus urge caution with the over-application of the notion of autonomy as a cure for instructional reform. Instead, the practice of engaged autonomy (Lamb et al., 2011) or connected autonomy (Fullan et al., 2022) may provide a pathway for leaders of instructional reform. Both concepts support the notion that teachers need ownership over decisions in their classrooms, supported by the development of a shared vision of equitable, student-centered instruction in collaboration with leaders and colleagues.

It is also likely that instructional autonomy played such a large role here because of the nature of elementary science education in the United States. As described earlier in this paper, both science as a subject and equitable, reform-based instructional practices are often de-emphasized or dismissed in elementary schools, especially in schools that serve historically marginalized students (Dorph et al., 2011; Hayes & Trexler, 2016). In these cases, instructional autonomy can allow teachers to create space for science and the time to plan for inquiry (e.g., Sandholtz et al., 2019). Yet, our findings also show that teachers can resist low instructional autonomy given enough self-efficacy, commitment, and PD, contributing to literature on teacher resistance of inequitable organizational structures (Carlone et al., 2010; Marco-Bujosa et al., 2020). In many elementary contexts, teacher "creative insubordination" may be necessary to teach equitable, reform-based science education, and thus is a potentially fruitful area of future research (Gutierrez, 2016, p. 679). In such contexts, PD can serve as a source of legitimacy and support for resistance (Hayes et al., 2019; Heredia, 2020; Zafrani & Yarden, 2022).

Professional impact is defined as the degree of influence teachers believe they have on other teachers in terms of science education, such as having the respect of other teachers and the opportunity to mentor others (Leithwood & Mascall, 2008). We place impact in the cultural dimension because support, respect, and sense of influence among colleagues are aspects of organizational culture. However, we acknowledge that impact has elements in the social (i.e., relationships with other teachers) and structural (i.e., opportunities to mentor) dimensions. Impact is less studied in PD literature, however studies on teacher leadership in PD have shown that teachers more deeply internalize reform-based instructional practices when they are able to mentor or influence other teachers (Amels et al., 2021).

In the present study, teachers' sense of alignment between the PD and existing district, state, and federal policies was significant in the correlational analyzes but did not retain significance in the final model. Alignment between organizational policies and PD has also been shown in the broad educational literature to greatly influence teacher uptake and implementation of new instructional practices (Kazemi & Hubbard, 2008). A handful of studies have confirmed similar relationships between alignment and teacher learning in science PD contexts (Allen & Penuel, 2015; Cherbow et al., 2020; Fore et al., 2015).

Eight organizational conditions were not significant in either correlations or mediation models, including: Cultural dimension: principal support, autonomy in class time, shared leadership; Social dimension: collaboration focus, collaboration culture, trust; Structural dimension: Science teaching resources; Policy dimension: Equitable science initiatives, equitable class time. Of these, we will speak to two areas—principal support (cultural dimension) and science teaching resources (structural dimension) because they have been a greater focus of research and practice. First, given that leadership support is one of the most tested and significant organizational predictors of teacher learning and change in PD (Banilower et al., 2007; Sandholtz & Ringstaff, 2016; Schipper et al., 2020) it was unexpected that principal support was not statistically significant in our models. This may be due to the pandemic context of the study; in California, principals were overwhelmed with distributing laptops, ensuring families received food, and tracking students (Gill, 2020). Teachers may not have seen them in a typical role of providing resources and communicating the importance of science. It is also possible that the autonomy (or lack thereof) due to the pandemic overrode the typical role of principals in shielding teachers from anti-science policies or aiding them in their reform-based pedagogies (Wenner & Settlage, 2015). Second, resources, such as textbooks and materials, were also statistically insignificant in the model, yet teachers did recognize their importance in the qualitative data, talking at length about how they worked to get materials home to students. This reflects much of what is found in the literature, which is that material resources themselves may not influence teachers' use of inquiry practices (Supovitz & Turner, 2000), yet are helpful when nested in other organizational supports, such as teacher collaboration (Hayes et al., 2020; Sandholtz & Ringstaff, 2016).

There is a need for additional research that replicates this exploratory study with a larger sample size, examining the role of a comprehensive and theoretically grounded set of organizational variables in predicting teachers' equity self-efficacy and their instructional practice in relationship to PD. A larger sample size would also enable testing the organizational variables as moderators of teacher learning, which could showcase how different aspects of the organization shape the pathway from teacher participation in PD to their implementation of target instructional practices. In addition, there is a need to understand how these relationships may differ depending on the school context.

5.3 | Teacher learning is not linear

Our integrated findings also show that teacher change emerged through an iterative and non-linear process amongst the main constructs of interest. For example, qualitative findings showed that for many of our teachers, self-efficacy and instructional practices seemed to act as a feedback loop, wherein trying out the approaches (aligned instructional practice) learned in the PD supported teachers' equity self-efficacy, which in turn encouraged them to implement more reform-based science education (instructional practice alignment). Although beyond the scope of this paper, an interesting focus of future research would be to understand whether and how such iterations create a positive feedback loop for teacher change.

Likewise, for many teachers, instructional autonomy allowed them to teach science in reform-based ways, which then increased their equity self-efficacy. For others such as Paula, equity self-efficacy allowed resistance in the face of low autonomy. These recursive interactions between self-efficacy and instructional practice have been documented in other studies (Lakshmanan et al., 2011), which show that teachers tend to learn through being exposed to new instructional practices or pedagogies, trying them out in practice, reflecting on student learning, and adjusting their beliefs in a recursive fashion, moving between personal characteristics (e.g., equity self-efficacy), the learning in PD, and instructional practice (Fore et al., 2015; Hayes et al., 2023; Schipper et al., 2017; Witterholt et al., 2012). Moreover, equity self-efficacy may not function to support reform-based instructional practice without instructional autonomy and opportunities to learn in a supportive environment (Holzberger et al., 2014). That said, complex models of teacher learning are only beginning to include organizational conditions as part of understanding teachers' iterative learning process (Schipper et al., 2017). This special issue in Science Education substantively contributes to building on this literature.

In sum, our findings underscore the essential role of teacher professionalism and sense of autonomy (conditions in the cultural dimension) over commonly cited organizational conditions in the structural dimension, such as materials and labs (Fore et al., 2015). The two significant organizational constructs are consistent with longstanding literature on teacher empowerment, which claims that autonomy, impact, and other agentive constructs, combined with PD and self-efficacy, create the opportunity for teachers to grow and manifest increasing competence in their profession (Pearson & Moomaw, 2006; Short & Johnson, 1994). Moreover, because the present study focused on *equitable* science instructional practices as the focus of PD and a key outcome, attention to instructional autonomy and impact in concert with teacher equity self-efficacy during PD may be a pathway towards moving the needle on equitable instructional practices in science education.

5.4 | Implications for practice

Shifting instructional practices in elementary schools to include more equitable, reform-based pedagogies is imperative for supporting students' long-term development as science learners during their progression through middle and high school (Maltese & Tai, 2010). Teachers need high quality PD to learn about and try out such practices, but teachers frequently encounter challenges in effecting changes to their instructional approaches, and research reveals considerable variability in the extent to which teachers adopt and incorporate reform-oriented instructional practices following PD (Sandholtz et al., 2019). Our study found that organizations that provide space for teacher autonomy and impact, in combination with professional learning opportunities and targeted support for equity self-efficacy, may create the best conditions for teacher growth. In other words, teachers need to be able to engage in their profession with agency (Pearson & Moomaw, 2006; Short & Johnson, 1994) while simultaneously learning about and trying out equitable practices with colleagues.

Granting teachers a degree of autonomy in selecting pedagogies, materials, and curriculum that they feel meets their diverse students' needs creates necessary opportunities for them to explore and implement reform-based instructional practices. However, it is crucial that such autonomy is combined with both collaborative opportunities to develop shared instructional vision across teachers and professional learning to support teachers in understanding their students and developing relevant pedagogical skills (Preminger et al., 2024). Without these essential supports there is a risk of teachers falling back on teacher centered instructional practices within isolated classrooms (Davis, 2003; Lamb et al., 2011; Rivera Maulucci et al., 2015). Such instruction-focused collaboration also serves as a way for teachers to mentor other teachers and provides avenues by which teachers can influence science instruction at their sites, increasing their sense of impact. By providing autonomy, avenues of impact, and support for collaborative learning, district and site leadership can empower teachers to embrace and effectively implement innovative teaching approaches that elevate student lived experience and meet their diverse needs (Davis, 2003; Lamb et al., 2011; Rivera Maulucci et al., 2015).

External PD projects can work with K-12 institutions to build capacity for such efforts, and recent research has shown a number of potential pathways by which to do so. For example, McNeill and colleagues (2022) have engaged in successful PD for principals around the Science and Engineering Practices (National Research Council, 2013), finding that principals were able to shift their understanding of strong science instruction over the course of their participation. Other past efforts have worked with district and site leadership through regular institutes to develop pathways for teacher leadership and shared decision making in science education similar to that taken by SLP (Hayes et al., 2020; Bae et al., 2016).

Conversely, if districts and sites are not ready to grant such autonomy, PD providers can support navigation of low autonomy by providing teachers time to discuss how to address organizational constraints collectively (Allen & Penuel 2015; Allen & Heredia, 2021). Likewise, PD such as SLP can legitimize resistance to anti-science organizational structures (Zafrani & Yarden, 2022). PD can also focus on building up teacher equity self-efficacy and understanding of student assets and learning needs, which was shown in our study to support resistance to organizational constraints (Gutierrez, 2016). Finally, PD providers can create avenues for teachers to develop their leadership capacities, increasing the potential for impact (Heredia et al., 2023).

5.5 | Limitations

A limitation to this study is the relatively small sample size. Although our sample size was sufficient for the analyzes conducted in the present study, a small sample does reduce the power of our analysis, and the ability to conduct multi-level models to account for teachers nested within schools. The small sample size also might have contributed to PD becoming non-significant in the final quantitative model. The difficulty of recruiting and retaining teachers in large-scale PD and quantitative research efforts is well known. Yet, cumulatively, findings of studies with smaller sample sizes, especially when they employ mixed methods, have been able to build up a body of literature on teacher learning in PD (e.g., Greenleaf et al., 2011; Lewis & Helding, 2015). In addition, we do not include in our model a pre-measure of self-efficacy. Some studies have shown that lower self-efficacy upon entry may result in greater learning and instructional change on the part of teachers (Granger et al., 2019; Settlage et al., 2009). Finally, aside from the measure of PD hours, the data is self-reported. While the nature of the data in this study constrains our ability to ascertain the accuracy of teachers' implementation of equitable reform-based instructional practices, video data of teachers' classrooms was collected as part of the larger project. In addition, teachers' perceptions of the organizational conditions such as autonomy and impact may more accurately predict teacher behavior than objective measures of such conditions, because for teachers, perceptions of constraints in the organizational environment may matter more than actual constraints (Hayes et al., 2023; Schipper et al., 2020; Stollman et al., 2020).

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

Data is unavailable due to participant confidentiality. We are able to share de-identified quantitative data upon request, qualitative data is unavailable due to Human Subjects Protection.

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