Collaborative Teacher Learning for Equitable Approaches to Science Education

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Abstract

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This dissertation examines how science teachers collaboratively learn to enact equity and justice-oriented approaches to science education within the day-to-day contexts of their professional work. In this study, I investigate how teachers navigate conflicting equity goals and develop pedagogical approaches that align with equity, sensemaking, and justice in science classrooms. Guided by situative theories of learning and pedagogical judgment frameworks, this qualitative study follows a group of public high school biology teachers engaged in professional learning over the course of eight months. Using a participant-observer design, data were collected through collaborative planning meetings, classroom observations, interviews, instructional artifacts, and analytic memos. Analysis focused on how teachers articulated equity goals, negotiated tensions among those goals, and shifted their instructional practices over time. I argue that the ambitious work of teaching social justice science issues using project-based units that position students with agency and expertise opened up a space for teachers to learn and attempt new approaches to instruction. Collaborative inquiry and iterations of a project-based climate change unit created conditions that supported meaningful instructional shifts. Over time, teachers moved toward more integrated conceptions of equity,

increasingly foregrounding student agency, productive uncertainty, and justice issues relevant to their local community. These shifts were reflected in both classroom practice and teachers' discourse about teaching and learning. While the teachers frequently experienced tensions among their equity-oriented goals, often reverting to traditional practices when uncertainty or competing demands emerged, they were able to navigate this conflict by prioritizing student agency and the instruction of complex social justice science issues. Implications are offered for the design of professional learning environments that support equitable and justice-centered science teaching, especially around teachers' need for support in recognizing the norms and routines of collaborative work that interfere with the complex work of pursuing multiple goals.

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I would like to acknowledge the extent to which Large Language Models, Computational Learning, and Artificial Intelligence (AI) are impacting society. While many people are choosing to use AI to complete tasks in their work and lives, many more people are not making this choice. And yet, due to the prevalence of AI being embedded in many of the essential services needed to complete work in our modern era, choosing to completely avoid using AI is not an option. Across this dissertation, I have made an active and deliberate choice to avoid using AI in any way that I can, including my work to transcribe episodes of recorded discussions by hand. I prefer this dissertation serve as a record of my own thinking, skills, and effort; therefore, this dissertation was created without using any form of AI, beyond the unavoidable forms such as search engines and spellcheck. From my observations in this study, the participating teachers did not use AI to generate their teaching models.

Dedication

I would like to dedicate this dissertation to all the students I have had the opportunity to teach, all my colleagues, and all my teachers over the years. All of you have taught me in your own way and helped shape this study.

Chapter 1. Introduction

Science teachers who want to better attend to equity and justice must coordinate many interlocking aspects of learning in their professional practice. Many teachers collaborate with peers in their community of practice to grapple with the multiple goals of equity-oriented science teaching. Teachers can often feel they are working at their limit, with little capacity to adopt novel approaches or pursue new goals. The work of teaching is complex and multifaceted, and teachers have to make numerous choices about how to spend their time (Jackson, 2002; Shavelson & Borko, 1979). As teachers collaborate to plan lessons and learning activities, they must coordinate many aspects of teaching and lesson development to meet students' diverse needs and address the multiple goals they have for improving their own practice. The work of transforming science education to be more equity- and justice-oriented requires attention to how teachers are grappling with their goals, often in collaboration with colleagues, and to how they navigate changes in their practices.

Equity and Science Teachers Learning

In the field of science education, there is a growing understanding of the need to attend to issues of equity, justice, and criticality in what and how science is taught, in order to account for the inequitable ways science education has served marginalized populations historically (Morales-Doyle, 2024; Morton et al., 2022). The Framework for K-12 Science Education (NRC, 2012) set forth standards that moved science education from defining content that students should know to locating student learning in the practices of scientists and engineers and the process of developing explanations and designing solutions, which required teachers to shift instructional practices and epistemologies towards student modeling, sensemaking, and designing of experiments (Allen & Penuel, 2015; Berland et al., 2016; 2015; NASEM, 2015).

Science educational researchers and teachers over the past decades have been calling for extending these reforms to also attend to issues of justice and equity, not just in the ways schools treat students, but across school systems, standards, and science teaching approaches (for example, Bang et al., 2012; Philip & Azevedo, 2017; Rodriguez, 2015).

Many teachers want to provide equitable learning opportunities for all their students and reduce disparities in success due to race, gender, language, or dis/ability, but they need support in transforming their practice and developing instructional approaches to achieve their goals. Working towards equity requires teachers to adjust and reimagine their practice in ways that don't reproduce the systems that have historically privileged certain groups, which in the United States are white, English-speaking, able-bodied, cisgender students (Picower, 2009). Science teachers who want to improve their classrooms to better attend to equity and social justice need opportunities to learn instructional strategies that can achieve their ambitious goals. However, taking up new forms of instruction requires conceptual, pedagogical, and ideological change around how classrooms function, how ideas are grappled with, and what goals instruction serves, concepts that might go against traditional norms and structures of schools (Carlson et al., 2019; Horn & Garner, 2022; Rodriguez, 2012). This study aims to explore how teachers engage in collaborative professional learning within the structures and contexts in which they work, and how a community of teachers shifts their conceptions of teaching as they attend to their goals of equity and justice.

Science teachers need learning opportunities to take on ambitious and equitable improvements to their practices. This requires learning opportunities that attend to the nuanced context in which they work, while also understanding how discourses inform the organization of schooling and the purposes it serves (Betancourt, 2024; Bowers, 2020; Bryk et al., 2015; Hayes, 2020; Spillane, 1999). Science education scholarship has explored numerous ways science teachers' professional learning can serve equity and social justice, such as; supporting diverse sense-making (Rosebery et al., 2016), centering racial justice (Mensah & Jackson,

2018), designing units around meaningful phenomenon (Morales-Doyle, 2017), using culture-based pedagogies (Bang et al., 2012; Thompson et al., 2021), disrupting ableism (Da Silva & Hubbard, 2024; Schmidt, 2024), promoting place-based learning and ecological caring (Bang & Medin, 2010), and expanding concepts of science to include families and communities (Barton & Tan, 2020; Bell, 2019; Tran et al., 2024). This literature promotes instruction that is complex, requires teachers to understand how to be responsive to students' sense-making, and use non-normative curricula and practices. Professional learning for science teachers must be equally ambitious, critical, and equitable (Kohli et al., 2015; Picower, 2015).

Significant time and money are invested in teachers' professional development in the United States, with estimates of $18 billion annually and each teacher spending 20-90 hours per year (Boston Consultancy Group, 2014). However, the impact of this time and money is highly variable, with many teachers reporting that their PD participation does not correlate with students' academic achievement (Kennedy, 2016; Sherff, 2018; Zuo et al., 2023). Teachers' on-the-job learning with peers is an important influence on practices and student achievement (Jackson & Bruegmann, 2009; Parise & Spillane, 2010). Such learning opportunities can take the form of informally organized peer interactions as well as formalized Professional Learning Communities (PLCs), with PLCs being shown to be particularly effective at supporting teacher learning through collaborative inquiry into teaching (Hord, 1997; Hargreaves, 2021). Job and contextually embedded learning opportunities support teachers' abilities to set collective goals, experiment with effective classroom practices, and collaboratively reflect on and reason with representations of practice (Bryk et al., 2015; Horn, 2010; Shim & Thompson, 2022). However, some studies have shown that teacher learning that lacks critical components addressing issues of equity and justice can result in the continued use of traditional practices that underserve students from marginalized populations (Admiraal et al., 2021; Barnes & McKinzie, 2024; Hudson, 2024). To answer the call for a more just system of science education, professional

learning must center on equity and justice while supporting teachers in transforming their practices.

Definitions of Justice and Equity

This study explores teachers' work and learning that moves towards equity and justice. It is important to attempt to define and provide a lens for these concepts. Both equity and justice are nuanced concepts that intersect with science education in various ways; therefore, I would like to elaborate on my views of each and explain how I use them across this dissertation. These frames and definitions help me interpret how the teachers in this study are working to make their classrooms more equitable. By using multiple frameworks for equity and justice, I can foreground different dimensions at different points in my analysis and understand the various purposes the teachers are working toward.

Attention to equity in STEM education has taken various forms over the history of modern education. Lee and Grapin (2025) describe traditional approaches that were “shaped by Western hegemonic epistemic beliefs and values, which determined the types of scientific knowledge valued in science standards and instruction” (p. 2258) to promote the most capable students into STEM careers. They contrast this with contemporary approaches informed by the Next Generation Science Standards (NGSS Lead States, 2013), which foreground student sensemaking and participation in the practices of science and engineering. Lee and Grapin (2025) point to the emerging future approaches that position students to address societal challenges by designing justice-centered solutions. These eras are not temporally defined, as each overlaps and is being taken up by actors across the system of STEM education today. The National Academies of Science, Engineering, and Medicine (NASEM, 2025) report, *Equity in K-12 STEM Education,* provides another view of five frames people take up across various educational systems and scales. As I explore further in this study, these frames provide another way to see how various ways of understanding equity serve different purposes. In this study, I

use the NASEM and Lee and Grapin's frameworks to understand the goals teachers are working towards and how their classroom enactments are influenced by the broader discourses of equity in STEM education.

For me, equity is both a process and a goal. While the goal is to achieve fair outcomes of rights, liberties, and status, the process requires attention to systems of inequality and the correction of historical harms. In education, this means attention must be paid to racism, linguicism, and other forms of bias that have produced historical and current barriers to educational opportunities (Neito, 1992; Patterson-Williams et al., 2020). Science teachers who engage in equitable practices would make concerted efforts to eliminate differences in educational opportunities. Teachers who center equity in their practice do so through multiple pedagogical approaches (Ladson-Billings, 1995; Parsons, 2005); how they interact with students, the classroom culture they establish, and the curriculum they adapt into daily lessons. Teachers respond to the lived experiences of their marginalized students and educate in ways that disrupt oppressive power structures. Equity-oriented teachers position students from marginalized communities as capable knowers and doers in the classroom, whose lives must be valued in their complexity. Equitable science education serves students with goals of justice and liberation.

In my view of justice, I draw from the work of the Benjamin Banneker Association (2017). In their use, they describe social justice as "a process to identify, examine, diagnose, discuss, and determine solutions to those political, economic, and social conditions that have an adverse effect on people of African ancestry" (p. 2). They identify three ways that justice is worked toward in the classroom: education *about* social justice, *with* social justice, and *for* social justice. A science class that teaches *about* social justice would include topics that link science to issues of justice. For example, a teacher might teach about the work of diverse scientists in order to challenge the view that scientists are only white, older men. Teaching *with* social justice means using pedagogical approaches that center students' voices, agency, and status with the goal of

equal learning opportunities. If a teacher establishes classroom norms for including diverse views and ways of communicating during a class discussion, this would be an instance of teaching with justice. Teaching *for* social justice in a science class uses the tools of science and education to work toward the goal of challenging and dismantling systems of oppression within and beyond the classroom. Examples of such work can be seen in Morales-Doyles' (2024) Transformative Science Teaching framework, in which students use their learning of science, such as heavy metal chemistry, to act as experts in advocating for more just policies around ground contamination. Science education that attends to justice must do so by teaching about justice, with justice, and for the purposes of justice.

These definitions of equity and justice overlap and intersect. Across this dissertation, I discuss both concepts in tandem and often interchangeably. While the frameworks used in the education literature provide a valuable tool for grappling with and analyzing equity and justice, in teachers' day-to-day work, such definitions are rarely used, and the concepts are not disentangled. In this study, I use the definitions as a lens to help me understand teachers' work, but I don't intend to claim that these frameworks are absolute constructs that function in isolation from one another in educational spaces.

Problem

The problem this dissertation addresses is that teachers can struggle to take up and enact transformative approaches of equity and justice in their science classrooms. This issue can stem from teachers who don't hold beliefs and values aligned with equity goals, or from worldviews that don't prioritize the process of working towards justice in a science education setting. The issue can also stem from teachers being unsure how to enact justice and equity goals that they do hold, due to a lack of examples or knowledge of justice-oriented science teaching practices. To explore how teachers make sense of their practices, beliefs, and values as they work, researchers have explored how knowledge systems function. Research shows

that people do not rely on “systematic theories for interpreting the… world, but on largely contextually sensitive knowledge elements, lacking systematicity, that serve as an intuitive basis for explaining… daily experience” (Wagner, 2006, p. 7). People make sense of their world in highly contextual ways, building understandings that are not always broadly consistent, as diSessa (1993) describes, knowledge-in-pieces. Building on this framework, Philip (2011) applies diSessa’s theory of conceptual change alongside Hall’s (1996) theory of ideology to explore teachers' sensemaking of socially constructed systems and discourses of power, stratification, and justice. Philips' ideology-in-pieces framework (2011) describes how situated and socially shared ideology can reinforce systems of power and domination, as teachers rely “heavily on taken-for-granted assumptions” (p. 305) to inform their grappling with their roles in school and their pedagogical responsibilities. For teachers who want to change how schools function to be more equitable, they must develop more “well-elaborated and internally consistent systems of thought’ (p. 305) as they come to see relevant contextual features, noticing how equity and justice play out at the intersection of content teaching, relationship building, and teachers' professional growth (Patterson Williams et al., 2020; Riley, 2025; Wagner, 2006). In refining their ideology and concepts of equity in science teaching, teachers can better enact lessons and teaching approaches that align with their equity goals.

How science teachers view their work is situated within the discourse around science education, influenced by peers, administration, school organizations, society, students, and the teachers' own experiences in schools. Each of these factors describes, determines, and constrains how science educators view their work. Messages that teachers receive from these diverse sources can conflict with one another, leading them to navigate the ‘contested terrain’ of science education (Philip & Azevedos, 2017). At the intersection of science education and issues of equity and justice, teachers must grapple with the complex responsibilities, goals, and practices that inform their work (Barton, 2003; Grinell & Rabin, 2017). Researchers have explored frameworks that show how equity is viewed by various actors in STEM education

(NASEM, 2025). Others have demonstrated the various approaches to equity adopted across different eras of science education and how each informs current science teacher work (Lee & Grapin, 2025). These reports show that traditional views of equity and science education focused on ensuring learners had access to the content and methods of science developed over the prior centuries, while leaving in place the systems of science and science education that perpetuate inequalities and harms to marginalized communities. More contemporary approaches to equity in science education have shifted away from the delivery of science content toward a focus on how learning makes sense of science phenomena while building the skills of science and engineering practices. Such approaches make space for more heterogeneous ways of knowing and doing science, as well as for students' agency; however, these frames are limited in their ability to redress harms done by the system of science, both currently and historically. Future approaches call for a more transformative vision of science education (Morales-Doyle, 2024). Researchers are calling for action to link science education to issues of justice and to the work of advocates of justice across society (Davis, 2022; Lee & Grapin, 2025; Philip & Azevdos, 2017). These frames envision the future of science education as cultivating ecological and cultural well-being by positioning science and science education in service of justice-oriented, interdisciplinary efforts to improve. Each of these frames and approaches informs teachers' work, and thus they must navigate the complex ways they overlap and guide their goals, shaping the craft of science teaching.

Additional research is needed to understand how teachers navigate working towards equity while refining their practices and meeting their professional responsibilities. It is vital to understand how teachers navigate their professional learning and to stay close to the context of teachers' day-to-day work and collaborations. To attend to these issues, my dissertation uses a situated and social practice theory of learning to explore how a group of science teachers learn through their on-the-job collaborative meetings. In this study, the teachers' context includes a district-wide initiative to improve literacy scores through disciplinary literacy instruction, attention

to issues of equity and student community, and attention to student scores on traditional standardized assessments. The participating teachers draw on these initiatives to inform their goal of developing equitable science teaching approaches. I explore the teachers' professional learning given these contexts by using a situated theory of learning to understand the subject-world relationship between teachers and the knowledge they are grappling with. I detail the resulting changes as an outcome of learning, the tensions or breakdowns in other non-ideal episodes, and the learning mechanisms of how the teachers' community of practice develops (Ball & Cohen, 1999; Lynch et al., 2019; Lave, 1996; Horn & Garner, 2022). The teachers who inform this study are influenced by the science education and equity frameworks and approaches described in the research as they plan, design, and deliver their lessons to students. By observing and participating in their work, I have gained insights into the co-evolution of teachers' classroom practice and their ideological stances.

Dissertation Organization and Research Questions

In this dissertation, I document teachers' learning as they work toward their goals to make their practice more equitable and just. I participated in the teachers' bi-weekly planning meetings and engaged in discussions about their goals and how they planned lessons to meet them. I used a case study design to describe teachers' learning of justice-oriented pedagogies during planning meetings and how they adapt this learning to their content classrooms. I analyzed teachers' discussions of pedagogical judgment and classroom observations to address my three research questions.

The following research questions are addressed in each of the findings chapters:

Research Question 1: How do teachers wrestle with enacting their stated equity-oriented goals?

Research Question 2: How do teachers collaboratively navigate tensions among their goals?

Research Question 3: How do ambitious project-based instructional units help teachers address equity goals?

The findings show that the teachers held three equity-oriented goals but generally prioritized clarity of instruction over students' sensemaking opportunities, and taught about justice issues without positioning students to act for justice. However, during a project-based climate change unit, the teachers, with support from the participant-researcher, disrupted their usual routines and approaches to their equity goals. The project-based unit's structural factors reinforced teachers' attention to preserving and foregrounding students' agency, choice, and creativity. The unit's focus on a social justice science issue allowed the teachers to position students as advocates and experts in addressing climate change in their local communities. As the teachers attended to the context of this climate change unit, they successfully navigated a seeming conflict between their goals of providing clear instruction and creating space for students to productively struggle and make sense of the content. This navigation emerged from complex discussions among the teachers about their pedagogical judgment, which revealed underlying goals and students' needs that the teachers could attend to.

In the following chapter, I review the literature on equity and justice in science education, as well as on teachers' goals, goal conflict, and how teachers navigate their goals. I illustrate my theoretical framing of situated learning and pedagogical judgment, and I provide a conceptual framework for how those bodies of literature inform the design of this study. In chapter 3, I explain the methods I used to carry out this study, including profiles of the participating teachers, the contexts in which they work, my role and positionality, and my approach to data collection and analysis. Chapter 4 addresses my first research question about teachers' stated equity-oriented goals and enacted practices. Chapter 5 addresses the second research question on how teachers navigate their goals. And in chapter 6, I explore a case of how the teacher addressed their equity goals through a novel unit structure. Finally, in chapter 7, I discuss how these findings speak back to the literature on equity in science teaching and how teachers navigate their justice-oriented goals. I provide limitations of this study, implications, and suggestions for future research.

Chapter 2: Literature Review

In this chapter, I explore what the science education literature says about shifts toward more equity- and justice-oriented approaches to student learning. The literature provides broad frameworks of equity in STEM that address how teachers and teacher educators are taking up the various aspects of equity and justice, and the challenges they face in navigating the fundamental shifts these frameworks call for. The body of work in this literature review shows how teachers enact equity and justice in their classrooms and what factors lead to teachers' resistance to equity-informed instruction. Further, this literature speaks to how teachers' goals provide a motivating force for action, learning, and change to understand how teachers are guided by the targets they set, and how their work is complicated by the interactions and conflicts among their goals. By focusing on conflicts arising from teachers' multiple goals, I discuss how teachers navigate tensions and the factors that can contribute to their prioritization of equity-oriented goals and pedagogy. I then provide the theoretical framework I use to analyze teachers' learning and changes in their pedagogical judgment.

Framing Equity in Science Education

Equity and justice have become essential topics in science education research over the last four decades. Multiple consensus reports have been published recently to address, define, and provide frameworks for equity and justice in science education (NASEM, 2022; NASEM, 2023; NASEM, 2025). These works take broad stances by examining the historical roles that science and science education have played in our society, naming the ways science education has promoted and upheld systems of injustice, and exploring how science education must be re-shaped across many scales of the education system if we are to redress those harms. While the consensus reports help lay out the ways equity and justice can be framed during decisions at the level of policy, funding programs, curriculum, assessment, and teachers' work with

students, a more fine-grained analysis is needed to explore how science teachers are taking up equity definitions and enacting them in their day-today work of teaching (Bancroft & Nyirenda, 2020; Davis, 2022, Jeong et al., 2023; Settlage & Williams, 2022).

Emerging scholarship in science education points to programs that center justice and provide evidence for ways teachers can contribute to reforming science education. In their Learning in Places Collaborative (2020), Bang and colleagues share work that supports building socio-ecological relations through connections to place, community knowledge, and students' sensemaking of multiple epistemologies (See also Bang & Medin, 2010). The work from Tan and Calabrese Baron (2023) aims to redefine who belongs in science classrooms, and what knowledge is foregrounded, making space for the "rightful presence" of marginalized students, families, and the inclusion of knowledge around political struggle, critiques of power, and science as a tool toward justice. Madkins and McKinney de Royston (2019; see also Madkins & Restrepo Nazar, 2022) have addressed racism and anti-blackness in their pursuit of racial justice through their framework of political clarity, which focuses on "how structural and school inequalities work to (re)produce differential learning experiences for minoritized learners" (Madkins & Morton, 2021, p. 239). This work shows how meaningful instruction can be connected to addressing systemic inequities. Additionally, Morales-Doyle (2024) has established a framework of *Transformative Science Teaching* that centers important social justice issues as the foundation of student learning and uses that work to develop students as transformative intellectuals in their communities, including acting as agents of change within the education system that has historically marginalized some. While these programs and research offer promising approaches to equity- and justice-oriented science education, rife with classroom examples that teachers can emulate, it is also helpful for teachers and researchers to have ways to organize these efforts and to understand how the various threads of work align toward shared goals of justice.

The *Equity in K–12 STEM Education: Framing Decisions for the Future* report (NASEM, 2025) provides descriptions of five equity frames used in decision-making across all levels of STEM education. Frames like this are helpful, not because they define equity as a single thing, but because they help us to understand how the concepts of equity and justice shift over time and in different contexts. By foregrounding a definition of equity in the decisions that actors in the system make, this report points to the agency people have to either reproduce or challenge harmful norms and approaches in science education. The decisions people make are tied to the goals they are working towards, as well as the purposes for which the STEM education system is designed (Rodriguez, 2015; Vakil & Ayers, 2019; Wissehr et al., 2011). Relevant to this study, the report describes how teachers use the five frames during decision-making as part of their work. These five frames are:

Frame 1: Reducing Gaps Between Groups

Frame 2: Expanding Opportunity and Access

Frame 3: Embracing Heterogeneity in STEM Classrooms

Frame 4: Learning and Using STEM to Promote Justice

Frame 5: Envisioning Sustainable Futures Through STEM

In this section, I will explain each frame through the lens of how teachers might use them in decision-making, as well as how those who serve teachers are working to support the uptake of these frames to promote a more just science education system.

Frame 1: Reducing Gaps Between Groups. In this frame, decisions are made toward the specific purpose of "reducing gaps between different groups based on race, social class, gender identity, or some other factor (e.g., immigration status)" (NASEM, 2025, p. 174). Gaps can take many forms but are often related to quantifiable and normative measures of standardized test scores, attendance, and graduation rates. Student interest in science, disaggregated by race or group membership or representations of groups in science curricula, is also a target of decisions

made by this frame. Teachers who use this frame may look at classroom data on grades or participation rates, and consider ways to equalize outcomes. They may consider ways to engage disinterested students or provide more examples of underrepresented identities in their lessons. Decisions made using this frame frequently do not address systemic and historical issues that have created the gaps, and instead identify individual students' needs and target interventions to address them. This frame also does not challenge the structures, priorities, or epistemologies that shape science education as a system.

Equity using this frame has long been critiqued as ‘gap-gazing’, which centers on perceived deficits of the individuals and communities that are hypothetically benefiting from it (Garcia & Guerra, 2004; Nieto, 2000; Rodriguez, 2001; Valencia, 2012). However, intervention programs continue to be designed with explicit goals of reducing achievement gaps between groups (Booth et al., 2015; Cabral-Gouveia et al., 2023; Jackson & Ash, 2012). While such interventions show statistically significant impacts in reducing achievement gaps, the studies fail to address historical reasons that led to the inequalities, and perpetuate Western heteronormative ideologies and norms of science that contribute to the exclusion of some groups (Kirchgasler, 2019; Medin & Bang, 2014).

Schools are driven by data-informed decision-making and funding tied to equitable student performance on standardized assessments (Every Student Succeeds Act, 2015; Learning Policy Institute, 2020). Teachers are affected by this foundation, especially in how they set goals and evaluate their own practice, with student scores being an easily accessible metric (Allen & Penuel, 2015; Bancroft et al., 2025; Harris & Liu, 2021). Additional decision-making frames for equity are needed to better critique and challenge traditional systems of science education, and teachers continue to need support in taking up critical frames.

Frame 2: Expanding Opportunity and Access. Decisions made using this frame focus on ways to explain students’ opportunities to learn by addressing barriers to access. This frame

continues to take into account the differences in access and opportunity experienced by various groups in science education, but looks to change the conditions that lead to the inequitable distribution of resources rather than directly addressing the outcomes at the heart of Frame 1. At a policy level, this may mean ensuring high-quality teachers and curriculum are distributed to schools serving marginalized populations, or funding out-of-school programs that provide additional learning opportunities for certain groups of students (National Science Foundation, 2018; Pinkard, 2019). Teachers who use this frame may decide to buy additional pencils, notebooks, or calculators, allowing any student without such resources to use them. They might translate instructional materials into various languages that their students are more familiar with. This frame can also motivate teachers to focus on core concepts and basic science skills, providing a foundation for students who may not have received it in prior coursework (Conger et al., 2021).

Efforts to redistribute resources to underserved populations suffer from the same deficit-oriented biases as Frame 1. While trying to provide resources to certain groups, decision-makers using Frame 2 can often fail to recognize the abundant resources a group already possesses (Denton et al., 2020; Yosso, 2005). Frame 2 uses the logic of fairness to achieve equitable outcomes, such that if all opportunities are equalized and fair to all students, then each student will have an equal chance at success. This fails to consider how inequities are built into the education system and does not address “what happens inside these learning opportunities, and whether they afford meaningful learning to students” (NASEM, 2025, p. 177). What counts as a meaningful learning experience for one student might differ from that for another, and thus, resource distribution would not change how the learning is perceived as meaningful. Research on teachers' efforts to expand students' opportunities and access to learning shows that reform guided by this frame faces significant challenges (Oakes et al., 1998). Teacher education grounded in curricular design and content expertise has the potential to improve and expand access to effective teachers (Short & Hirsh, 2022); however, this leaves

in place the ways that science education is built on Western epistemologies and doesn't address issues that can lead to inequitable participation. A recent study by Stroup et al. (2026) demonstrates that attending to equitable participation requires creating classroom communities in which students feel valued, including expanding the norms of discourse deemed acceptable in scientific sensemaking (See also McGee, 2020).

Taken together, NASEM's (2025) Frames 1 and 2 share conceptual overlap in that they both attend to gaps and differences that can be observed and measured across populations resulting from how science education and society position learners. They also fail to attend to the historical ways in which science education has impacted various populations, nor do they attempt to change the norms or the ways in which science education is structured. When comparing to Gutiérrez's (2012) framing of equity, these two align with the *dominant axis* of access and achievement. Gutiérrez's critical axis of power and identity is not seen in these frames. Additionally, in describing four discourses that inform science learning and equity, Philip and Azevedo (2017) point to efforts in science education to increase student achievement and to design science education that helps marginalized groups better identify with science. Across all of these conceptions of equity in science education, each points to the merits of frames of access and opportunity, identifying goals of eliminating achievement gaps and providing students with access to the tools of science. However, they also point to the need for additional frames that challenge the purposes of science education and the ways in which systems of oppression currently shape it.

Frame 3: Embracing Heterogeneity in STEM Classrooms. This frame reimagines both which epistemological sources are accepted as science and which identities, cultures, and values are included in the endeavor of science. Students' diverse sensemaking is placed at the center of learning experiences, and students are provided with opportunities to grapple with multiple epistemologies that reflect our pluralist society (Bang et al., 2012; Hodson, 1999; Nasir et al.,

2021). Teachers take up this frame when they make decisions to elicit students' ideas and experiences and to use those ideas as valuable parts of scientific inquiry. Teachers may encourage students to use their full linguistic and semiotic resources to explore their ideas (Rosa & Flores, 2017). In so doing, teachers embrace the diversity of sources of ideas and modes of communication as valuable to students' learning. This also challenges traditional science norms that dictate a single way of communicating and a single canon of science. Additionally, science teachers take up this frame when they feature examples of phenomena and approaches to inquiry based in the lives and cultures that are relevant and sustaining for the students in their particular class (Moll et al., 1992; Paris & Alim, 2017).

Many contemporary efforts to reform science education aim to improve teachers' ability to recognize and value heterogeneity in science education. By laying out a set of core practices for science teachers, Windschitl and Calabrese Barton (2016) argue that science education based on practices of student sensemaking is an effective way to work toward equity. To support teachers' uptake of students' ideas, Rodriguez (2004) designed learning centers to engage teachers in investigating, embracing, and using students' knowledge in authentic learning activities. Extending beyond the classrooms, research by Tzou et al. (2020) co-designed learning along with educators and families that feature storytelling as a learning resource drawn from community members' lives to explore principles of robotics and engineering.

Research also shows the complexities that emerge as teachers embrace heterogeneity in sensemaking and science content, and the ways they navigate these complexities while remaining committed to equity. From the outset of preservice education, emerging teachers must grapple with their own ideological positions while learning pedagogical moves that may differ from their experiences in science education (Rodriguez, 2004). Braaten et al. (2022) show how preservice science educators use dissonance between various visions of teaching to navigate and grow their own expertise. Science teaching that embraces diverse sensemaking can uncover seeming conflicts between norms in school that encourage student convenience

and the goals of argumentation and critique, yet these conflicts can yield productive learning opportunities (Carlone & Lancaster, 2024). Gonzales-Howard and McNeill (2019) also show how teachers navigate the complexities of surfacing individual students' ideas and experiences and using them as resources to build classwide consensus and understanding of science ideas. These efforts go against traditional approaches to science education that feature lectures on science content and, in doing so, reshape the authority of ideas in a science classroom away from the teacher and individuals towards the collective sensemaking of the community of learners.

Frame 4: Learning and Using STEM to Promote Justice. The NASEM (2025) report describes this frame as “learning STEM not as an end for its own sake but as a resource within movements for social and sociological justice” (p. 181). Decisions made using this frame see science as a tool that can support communities' efforts to achieve justice. While some of the previous frames attempt to change conditions that might be contributing to achievement gaps with the goal of helping certain groups better fit within science, this frame reverses that logic by reframing how science education serves communities and sets the goal of science as working to address the needs of underserved communities. Teachers using this frame may choose to design lessons around a local issue that their students or their students' families are grappling with. Teachers may select phenomena tied to socio-scientific issues and position their students as agents who can actively make change within their communities. The definition of social justice teaching from the Benjamin Banneker Association (2017) fits within this frame, pointing to teaching about social justice, with social justice, and for social justice.

While national learning standards for science have been criticized for failing to address issues of justice and equity (Rodriguez, 2015), researchers and teachers have been exploring ways to design instruction that foregrounds the link between science and justice. Calabrese Barton & Tan’s (2020) framework of “rightful presence” extends the ideas of inclusion by calling

for the integration of political struggle, the recognition of the intersection of justice and education, and attention to issues of power within and beyond the classroom. Extending this work, Calabrese Barton et al. (2021) show how science learning that centers justice and learners' historicized knowledge opens up opportunities for both students and teachers to shift the relationality of power in science education. Recent work by Morales-Doyle (2023, p. 92) explores how“transdisciplinary curriculum prioritizes generative themes and poses as an open question the role of scientific ways of knowing in struggles for justice,” drawing on Freire's conceptualization of justice. A long-term partnership and study by Segura et al. (2021) illustrate how a community-driven school near Chicago positions students and their families to learn science as they engage in work to eliminate a local pollution source, participate in activist campaigns, and link problematic economies to the changing climate. Many of the projects that attend to this frame further challenge current science standards, which are primarily organized by the ‘hard’ sciences (Biology, Chemistry, Physics, Earth Science), by including additional approaches to science such as geo-cultural-spatial mapping, ethnographic studies, and the intersection of the built environment, ecosystems, and human cultures (Burgess & Patterson Williams, 2022; Bang et al., 2016; Talor & Hall, 2013).

Frame 5: Envisioning Sustainable Futures Through STEM. Central to this frame are the purposes that STEM education serves: “to cultivate equitable, just, and thriving social and ecological futures that attend to and support both ecological and human wellbeing” (NASEM, 2025, p. 184). Building on Frames 3 and 4, which embrace heterogeneity and work towards justice, this frame takes an explicit view of the future to consider ways new patterns and systems of STEM education might address future matters of sustainability, both culturally and ecologically. Teachers who use this frame during decision-making may explicitly draw from knowledge sources that traditional STEM education has attempted to erase (Madden, 2023; Young & Young, 2025). Teachers might use interdisciplinary learning to address the persistent

challenges in education by centering the exploration of responsibilities and relationships to nature (Mawasi et al., 2021). Translanguaging efforts in science education also operate within this frame when learning activates students to use their full linguistic and semiotic repertoires and various communication modalities to reinforce language learning alongside science learning (Garza & Arreguín-Anderson, 2018; Suarez, 2022).

The envisioning of sustainable futures this frame calls for requires an ambitious yet necessary shift for science teachers, one that entails teacher learning about instructional orientations and relationships in science classrooms. Research in this area examines ways lessons beyond education can inform teachers' learning, such as learning from ecological knowledge and lifeways that shape new arrangements for sustainability (Shamon et al., 2022). The Learning in Places Collaborative (2020) is helping teachers by providing frameworks and curricular resources that explore socioecological decision-making and center nature-culture relations and students' engagement with ethical responsibilities to nature (Tzou et al., 2021). Cochran et al. (2020) draw on critical race studies to critique apolitical views of science while showing examples of how people across the globe have engaged in politically oriented science, invention, and the imagining of possible futures. These approaches are presented to reshape STEM education and reform teaching practices. Other researchers are looking towards utopic visions of the future to explore ways that educators can teach science, accounting for larger time scales than are typically presented in science classrooms while also exploring concepts of progress in STEM that need to be redressed (Gutierrez et al., 2020; Jones & Howard, 2022; Rajala et al., 2022). In addition to the changing pedagogical approaches implied in this frame, researchers are also looking toward changing perspectives on diversity, the need to engage in sustained relationship building and power-sharing, and the ways STEM education supports pluralism in society (Medin et al., 2017).

Understanding the *Equity in K-12 STEM Education* report as a trajectory

Decisions about how to address equity across the various levels of STEM education are being made using all the frames the NASEM (2025) report lays out. Examples of each frame can be found in the literature over many previous decades; however, historical trends reveal that equity and justice have not always played a significant role in science education (Gutek, 1986). Even in more modern times, attention to equity has prioritized equal access, while resistance to issues of justice that challenge the status quo persists (Tran et al., 2025; Tyack & Lowe, 1986). Drawing on the 2025 NASEM report and recent others (NASEM, 2022, 2023), as well as studies by a range of researchers, Lee and Grapin (2025) describe a trajectory of three eras of science education with a focus on equity and justice. Lee and Grapin's position paper points out that each era they describe overlaps, and efforts aligned with each can be seen in current research, yet their description provides a framework that is helpful for examining how change is occurring and the directions future efforts may take.

Each of the three eras and approaches to science education prioritizes and illustrates some of the frames discussed above. In the era defined by traditional approaches, scientific knowledge was seen as a fixed canon that only some students were expected to master because of their innate interest in the discipline. In this era, teachers who sought to address equity sought to provide clear access to science instruction, with students positioned as recipients of knowledge (Deboer, 2014). Frames 1 and 2 would most often be prioritized through this traditional approach. The next era of contemporary approaches is dominated by efforts that "promote equity as students make sense of phenomenon… similar to what science and engineers do in their professional work" (Lee and Grapin, 2025, p. 2257; NGSS Lead States, 2013). This era aligns with *Frame 3: Embracing Heterogeneity,* as it centers students' diverse sensemaking as the primary source of learning rather than the scientific canon, while also promoting student agency to build the skills necessary to attend to diverse challenges in

students' futures. Finally, Lee and Grapin describe their third era as proposed future approaches that promote the design of justice-centered solutions and the leveraging of multiple epistemologies across STEM subjects. In this era, students are positioned as advocates for the future growth of justice and liberation. NASEM's (2025) Frame 4: *Learning and Using STEM to Promote Justice* and Frame 5: *Envisioning Sustainable Futures Through STEM* align with this approach.

Whether teachers have been in the classroom for 30 years or are completing their teacher education coursework, they are influenced by the many frames and messages of how to attend to equity and instruction. The three approaches to equity in STEM education outlined by Lee and Grapin (2025) follow a general trajectory of change. Teachers must navigate shifts in approach. This can look like internalizing the concepts and changing one's practice, transforming the concepts in ways that shed light on theory, or resisting the changes in the form of maintaining pedagogy, ideology, or both (Rodriguez, 2005).

Researchers have been exploring the ways teachers learn and navigate these changing approaches to equity. In an effort to support teachers to take up transformative justice education, Patterson Williams and Gray (2019) identify five commitments that teachers must make. These are "a commitment (1) to an ever-developing self-awareness, (2) to science and its practices, (3) to science as a transformative agent, (4) to their students' social emotional wellness, and (5) to restorative practices" (p. 328). Building on this approach to pedagogy and the development of teachers' self-awareness, Patterson Williams also explored how to support teachers' focus and awareness of equity-related classroom moments by cultivating their "inner witness" (Patterson Williams et al., 2020). Similarly, Kang and Nation (2022) developed their *Transforming Science Learning* framework to support teachers in learning to step back, using co-design, to an intermediate level of abstraction around classroom events, enabling better sensemaking before responses are made. Kang and Nation provide an example of this intermediate level of abstraction as a group of teachers unpacked how to *attend to race,*

language, and identities by discussing how that might happen in their own classrooms, as opposed to being guided by a higher-level principal, such as *promoting justice.* Taken together, this research shows how professional learning and reform efforts can fail if they focus only on surface-level changes to curriculum and teaching tricks, without developing teachers' ideological commitments and attunement to equity in lesson planning, classroom interactions, and all aspects of teaching.

To support teachers' uptake of equity orientations, attention must be paid to both systemic work norms and individual behaviors. Routines and norms become implicit ways of acting within a community and can mask the impact they have. Resistance to taking up equity can manifest as equity detours, which Gorski (2019) describes as actions people take “to protect their privilege and avoid the messy work of racial justice” (p. 57). Gorski illustrates these equity detours as discourses schools employ, such as pacing-for-privilege, the poverty of culture, deficit ideologies, and celebrating diversity, which allow teachers and school leaders to avoid grappling with how racism and inequalities inform how schools work. To address these issues, researchers are looking beyond individual teachers' professional learning to examine how an infrastructure of support can help districts and organizations drive change (Penuel, 2019). Using a series of STEM Teaching Tools, Bell (2019), in collaboration with teachers and educational leaders, developed briefs that integrate practice, research, and policy to support the uptake of equity orientations in STEM education. The work of moving from traditional approaches to equity and education towards future justice orientations is happening at the individual and system levels. However, there is limited research that explores teachers' learning in response to messages and tools that promote equity and justice, such as those I described above. Additional research is needed to examine how these efforts are being rolled out and to provide qualitative descriptions of learning in these conditions.

As science teachers navigate the changing landscapes that are calling for more ambitious and equitable approaches to students' learning of science, and the shifting views of

epistemologies that inform science education, they must learn how to structure their practice to align with new goals while also attending to frames that continue to inform the system of education. In the next section, I explore how teachers set multiple goals to take up pedagogical and ideological change, and how those goals can support or hinder their efforts.

Science teachers' goals and goal conflicts

In this study, I examine how teacher groups engage in professional learning through the collaborative, group-directed, day-to-day work of teaching towards the goals of equity and justice. The literature on professional learning and educational change highlights the importance of teachers' agency in engaging in collaborative, contextually grounded learning processes (Czerniawski, 2013; Hoban, 2002; Kennedy, 2011; Little, 2012; Lohman & Woolf, 2001). Both individually and group-directed teacher learning differ from professional development directed by an outside agent, with the essential condition that teachers' intentional learning is tied to their awareness of their learning goals and how their practices align with those goals (Janseen et al., 2012). While much of teachers' learning is unplanned and reactive to emergent conditions (Vermunt & Endedijk, 2011), intentional learning is tied to teachers' desired change in behavior or cognition related to the practical work, beliefs, and orientations of teaching (Fenstermacher, 1994; Putnam & Borko, 2000; Zwart et al., 2008). Teachers who set learning goals are active agents who guide their professional learning to address the issues they encounter in their teaching contexts.

Goals are the “cognitive representation of a desired end state” (Fishback & Ferguson, 2007, p. 491) and serve as the foundation of motivation, being tied to contextual factors, and serve as the driving force behind action, according to goal-setting theory (Kruglanski et al., 2002; Lock & Latham, 2013). Research has documented the effects of teachers' goals on their instructional actions in the classroom, including orientations towards mastery (Retelsdorf & Günther, 2011), differentiation (Bishop et al., 2020), and resilience in the face of learning

disruptions (Shutz et al., 2020). Over the course of a teacher's career, the many goals a teacher holds evolve in response to changing conditions (Hagger & Malmberg, 2011; Kang, 2008; Tsang, 2018). In addition to instructional practice, how teachers navigate multiple goals and achieve them affects teachers' well-being (Boudreaux & Ozer, 2013). Researchers have shown that pursuing multiple goals increases teachers' cognitive load, making decision-making more complex, which affects teachers' sense of self-efficacy and motivation (Gorges et al., 2022; Gray et al., 2017; Kelly et al., 2015).

While prior research has focused on how teachers have navigated individual goals, such as self-regulation (Zimmerman, 2000), beliefs (Buehl & Beck, 2014), and orientations (Wang et al., 2013), the processes and structures of multiple goal pursuit have received attention only more recently (Gorges et al., 2022; Palmer, 2023). Sun and Frese (2013) described a framework in which multiple goals can be reciprocally interdependent (i.e., supporting one another), sequentially interdependent (i.e., one goal being required to be satisfied before another), or multiple, separate (i.e., goals independent of one another). While sequentially interdependent goals can result in tension due to the prioritization of one goal over another (Presseau et al., 2013), multiple, separate goals are most likely to lead to goal misalignment and conflict (Emmons et al., 1993).

Goal conflict is an important topic for teachers' professional learning, as it can affect teachers' satisfaction and motivation and, in turn, instruction (Gorges et al., 2022). Goal conflict is the condition in which “a goal that a person wishes to accomplish interferes with the attainment of at least one other goal that the individual simultaneously wishes to accomplish” (Emmons et al., 1993, p. 531). Researchers have found that people take up various strategies to deal with goal conflicts, such as disengaging with or abandoning a goal (Kung & Scholer, 2019), attempting to balance goals through multitasking (Adler & Benbunan-Fich, 2012), or modifying goals through prioritization and nesting (Höchli et al., 2018; Orehek & Vazeou-Nieuwenhuis, 2013).

Studies on teachers' goal conflict identify two types that frequently arise in educational settings: resource-based and inherent goal conflict (Gorges et al., 2022; Hutner et al., 2022; Jones, 2003; Mansfield et al., 2012). Resource-based conflict is due to the experience of limited resources, such as time, energy, or materials, that prevent multiple goals from being achieved. Inherent goal conflict arises from essential incompatibilities between goals or goal strategies, such as following a curriculum with fidelity versus adapting it to students' needs. Inherent goal conflicts are not ones that can be resolved by achieving both goals, which requires teachers to deal with ‘endemic uncertainties’ (Lortie, 1975) and contradictions between goals (Helsper, 2004). The result of inherent goal conflicts is that one or more goals are abandoned, which can negatively impact teachers' feelings of success and self-efficacy.

Much of the research on goals, goal conflict, and how teachers navigate multiple goals draws on a theoretical and methodological foundation rooted in psychology and the internal cognitive processes of individuals. While this provides a helpful launching point for investigating goal pursuit, much of this literature has minimized the contexts of goal pursuit and the ways goals are pursued within communities of practicing teachers. For example, in a study by Freund and Tomasik (2021), the researchers designed a study to explore how participants' age influenced how they resolved goal conflicts. They simulated goal conflict using two tasks, a riddle and a sorting task. While this approach helped to isolate the measured factor of age, it removed the complex nature of how diverse and integrated goals are solved in day-to-day conditions. For science teachers who are navigating goal conflicts, for example, conflicts between teaching science content and being responsive to students' diverse interests, such an isolated experimental approach would not be appropriate.

Moving beyond abstracted experimentation and psychological studies, research that takes a more situated approach to account for the contexts of teachers' goal pursuit has yielded concerning insights that warrant more attention. Wallace and Kang (2004) found that science teachers in one school experienced goal conflict due to differences in epistemological beliefs,

which led to limited collaboration and professional learning. In a survey study of 161 middle and high school science teachers, Aydeniz and Southerland (2012) found that teachers struggled to clarify goals around student learning and their own professional development due to conflicting messages from state and school district policies. The ambiguity in the goals and purposes that science education serves often results in science teachers grappling with conflicting goals (Allen & Heredia, 2021; Allen & Penuel, 2015; Heredia, 2020).

These impacts of goal conflict extend to students' learning as well. In a study by Gonzalez-Howard and McNeill (2019), two science teachers collaborating on a lesson implemented it using different strategies because they had different, tacit primary goals: iteratively improving argumentation skills versus building a class-wide shared understanding of a science concept. The different goal framings of these two teachers led students to experience two distinct learning outcomes. In a study by Smith and Southerland (2007), it was found that goal conflict led to more traditional instructional practices as teachers grappled with “substantial uncertainty and frustration” (p. 415) and had unclear expectations of what they were supposed to be doing, thus returning to more comfortable teacher-centered instruction.

For these reasons, more studies are needed to explore how science teachers experience goal conflict, how they navigate the tensions that result, and what processes help teachers to move through conflicts, especially when considering the intersection of equity, justice, and science teaching. Empirical research on “teachers' multiple goal pursuit and its implication for instructional practice is rare” (Cho & Shim, 2013, p. 18), and there is a need for an understanding of the in-situ context for and process of goal conflict resolution. This is especially true when teachers set goals based on their own priorities and beliefs rather than top-down educational reform efforts (Hord, 1997; Hutner et al., 2022; Shim & Thompson, 2022). And further, in a time of increasing awareness of the need for education to better address issues of equity and social justice, studies are needed to explore how teachers navigate goals that intersect with bias, power, justice, and science content.

Theoretical Framework

As a theoretical foundation, I use a situative and sociocultural lens to view teachers' learning. Situative learning theories stand in contrast to cognitive and psychological learning theories that use binary frames of skills and concept acquisition, with ideal pathways of learning that move individuals from lacking to achieving a fidelity of practice (Lave, 1996). In this study, I focus on the "relational character of knowledge and learning, the negotiated character of meaning, and the…engaged, dilemma-driven nature of learning activities" (Lave & Wenger, 1991, p. 33). Situated learning sees knowledge developing through participation in activities and learning that is generalized through the activities of a community, filled with context and culturally significant meaning for that community (Eisenhart, 2001; Greeno, 2006). A sociocultural practice theory of learning helps me to examine the role that teachers' context, participation, spatial movement, institutional norms, and social aspects play in their collaborative learning (Dreier, 1999; Penuel et al., 2017).

To examine teachers' learning and goal setting regarding their science teaching practices, I build on a theory of learning grounded in Jean Lave's (1996) view that learning theories must stipulate three aspects: a *subject-world relationship*, a *telos*, and *learning mechanisms*. I draw on Hall and Jurow's (2015) use of subject-world relations to describe teachers' s conceptions of teaching, their participation as active agents in the communities of practice, and the shared representations of practical activities that function as sites of negotiation for problems and shared understandings. The outcome, or telos, of teachers' learning can be seen in changes in the organization of instruction, the nature of classroom discourse and linguistic repertoires, and teachers' growing sophistication and elaborations in episodes of pedagogical judgment (Horn, 2019; Horn & Garner, 2022). Finally, the learning mechanisms are theorized to come from the process of teachers drawing on their conceptual resources, engaging in pedagogical judgments, and integrating refinements of those concepts

into practices as part of the community of teachers (diSessa, 2006; Greeno, 2006; Hall & Jurrow, 2015; Rosebery et al., 2010). As teachers engage in consequential learning as a community, they move from identification of shared problems and goals to meaningful changes in their relations, conceptual resources, and systems of activity. Next, I explain how I use theoretical frameworks for pedagogical judgment to explore teachers' situated learning.

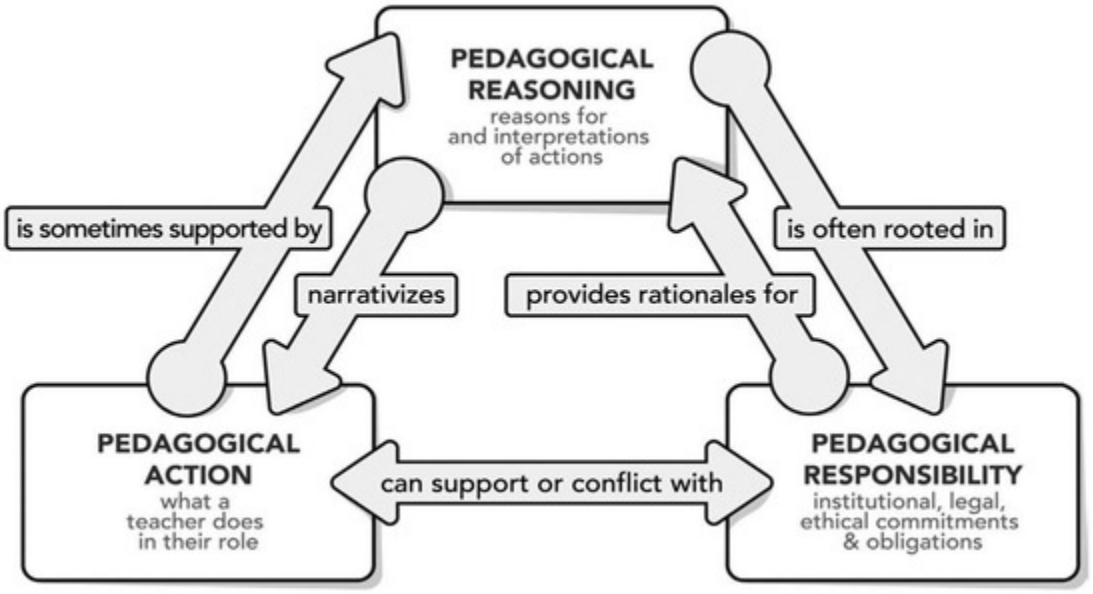
Pedagogical Judgment

Teachers make countless decisions every day, and learning as a teacher involves building and refining one's ability to make decisions that lead to educational success (Borko et al., 1990; Jackson, 1968/1990). Teachers who hold goals of transforming education to better center justice and equity must make decisions about how to attend to heterogeneous student sensemaking, adapt curricular resources to be responsive to specific students, and apply theoretical principles of practices to situated and nuanced teaching contexts (Cohen, 2011; Horn, 2019; Lortie, 1975). Many of these decisions are made by teachers in collaboration with colleagues. Lefstein et al. (2020) argue that teachers' on-the-job discourse and collegial discussion are key sites of ‘pedagogically productive’ teacher talk that allow teachers to build shared conceptual understandings of the work of teaching and better align their practices with their goals. Horn and Campbell (2015; Horn, 2019) have described these sensemaking discussions between colleagues as a process that develops *pedagogical judgment*. Research continues to need to explore how these discussions support science teachers’ learning of equity-oriented practice.

Pedagogical judgment can be “a productive framework for sharpening teachers’ responses to pedagogical dilemmas” (Horn, 2019, p. 322) as they engage in discussion with peers which functions to change participation among those in their community of practice. Teachers engaging in discursive episodes of pedagogical judgment refine their capacity to interpret classroom events as more ecological and to recognize students’ diverse sensemaking

as educationally significant (Ball & Cohen, 1999; Fine, 2020; Horn & Garner, 2022; Shim & Thompson, 2022). Horn describes pedagogical judgment in three parts. Teachers discuss their (1) *pedagogical actions* that are supported by (2) *pedagogical reasoning,* which is often rooted in (3) *pedagogical responsibility* (Horn, 2019, p. 324. See Figure 1). Pedagogical actions refer to what a teacher does in their role, including “the intentional and unintentional choices teachers make” (Horn & Garner, 2022, p.59). Because much of teachers' collegial talk occurs asynchronously from the acts of teaching, pedagogical actions are either discussed as replays of past instructional acts or as rehearsals and planning that anticipate actions (Horn, 2010; Lewis et al., 2006). Pedagogical reasoning occurs in the moments of talk in which a teacher explores the reasons for an action or teaching practice (Horn, 2005). These moments of talk reflect the teachers' interpretations of a practice or rationale that serves as the foundation for a chain of reasoning, pointing to what is knowable about teaching and how to know it (Horn & Kane, 2015). In sustained discussion of pedagogical reasoning, teachers refer to their responsibilities and link them to specific actions. Pedagogical responsibility “describes teachers’ engagement with their sense of their obligations, whether to ethical principles or situational constraints” (Horn, 2019, p. 325). The sense of responsibility comes from various sources, such as institutional norms, legal doctrines, and internally held beliefs and ethical principles. Responsibilities are often an underexamined aspect of pedagogical judgment (Horn & Garner, 2022). These responsibilities serve as guides and anchors for actions, while also reflecting their commitments and teaching goals.

Figure 1. Pedagogical Judgment Components Taken from Horn & Garner, 2022, p. 56.



In this study, I use pedagogical judgment as an analytical framework to evaluate the actions, reasoning, and responsibilities that teachers consider in their workplace discussions. The three components of pedagogical judgment allow me to build an understanding of the resources teachers draw on, identify the areas of growth and areas of struggle for the teachers in this study, and construct an explanation of how the teachers are working towards their goals. Horn and Garner (2022) used this framework to develop a description of math teachers' learning towards ambitious and equitable goals. The refinement of pedagogical judgment is a valuable process for attending to equity and justice. Teachers' judgment can function to exclude or marginalize students, or, alternatively, work towards inclusion and transformative educational spaces (Alton-Lee et al., 1993; Daniel et al., 2023; Marshall & Horn, 2025; Morris, 2015).

Extended, sustained conversations between teachers that evoke pedagogical judgment are not the most common form of teachers' talk. In a 4-year study of 16 schools' workgroup conversations, Horn et al. (2017) found that two-thirds of teachers' meetings did not include

attention to pedagogical reasoning and responsibility, instead focusing on “practical details of lesson planning… and coordination of pedagogical action rather than on uncovering pedagogical reasoning and responsibilities” (p. 327). Horn et al.’s study categorized conversations based on how they supported teachers' concept development and supported future actions, finding that conversations about pacing (when things should be taught), logistics (what topics should be taught), and tips and tricks (monologic talk on how to do things) made up 67% of the sampled meetings. Horn et al. claim that teachers' concepts were not developed in these meetings because they did not surface teachers' connections to their reasoning and responsibilities, and were typically dominated by a single speaker. The remaining third of the meetings sampled, however, involved shared interpretations of teaching work that analyzed why certain instructional actions should be taken. The rarity of exploring the ‘why’ of pedagogical actions allows tacit assumptions about instruction to remain unchallenged, limiting the transformation of education to better serve equity and justice.

Much of the research that draws on pedagogical judgment explores teacher discourse that is reflective and richer, offering more opportunities to elicit teachers' reasoning and responsibilities (Ehrenfeld et al., 2025; Horn, 2019; Horn & Garner, 2022; Janis et al., 2020). These studies typically center on teachers' analysis of teaching actions as they take retrospective views of lessons that have already occurred. Researchers have studied how teachers engage in conversations by viewing a recorded video of a past lesson, which helps them see and remember students' comments and responses (Horn, 2019; Horn & Garner, 2022). Additionally, Ehrenfeld et al. (2025) studied teachers' conversations in situ, during collective grading of an assignment students completed, and Janis et al. (2020) featured debrief conversations with pre-service teachers who had recently facilitated a lesson with students. These important cases show how teachers exercised pedagogical judgment by looking back in time at classroom representations to discuss dilemmas and the specific impacts on students. However, being that the majority of teachers' on-the-job discourse is not structured to engage in

reflective thinking (Horn et al., 2017), there appears to be a need to understand how teachers' forward-looking, planning-focused meetings might also contribute to the refinement of their pedagogical judgment. While Horn et al. categorized the planning meetings they observed as 'low depth meetings' due to the infrequency of deeper discussion of pedagogical judgment, I found in this study that teachers' pedagogical judgment is engaged during planning and logistics meetings. I argue that researchers would benefit from understanding what discursive moves initiate discussions of pedagogical judgment during planning meetings, which I take up again in the discussion section of this dissertation.

In this study, I attended teachers' collaborative planning meetings explicitly organized to focus on forward-looking discussions of pacing, content planning, and teaching strategies. In these meetings, the teachers planned upcoming lessons in line with their equity-oriented goals. Unlike Horn et al.'s (2017) findings, these conversations often included teachers' collective interpretations of instruction and engagement with pedagogical judgment. Researchers have pointed to the value of pre-active reflection and planning in developing teachers' expertise while also attending to the situational context of the work of teaching (Enow & Goodwin, 2018; Lewis et al., 2006; Lowyck, 1986). In the planning meetings of my study, the teachers' discussions that elicited their pedagogical judgment contained important features of talk that initiated discussion of pedagogical action, reasoning, and responsibilities. While planning, the teachers frequently proposed ideas and offered suggestions to one another about the routes of action they might take in future lessons. These provided launch points for discussions in which teachers evaluated the action, modified, extended, or critiqued each other's ideas, while considering the situated logistics of taking that action and surfacing each other's reasoning and responsibilities. Throughout this study, I refer to these discursive moves as teachers' *propositions*, as they indicate how the teachers were suggesting a pedagogical action that aligned with one or more of their teaching goals. Propositions helped the teacher to engage in high-depth learning

conversations, refine their pedagogical judgment, and mobilize their future work within specific constraints.

Proposition statements are analytically distinct from a similar form of talk called *rehearsals,* in which “teachers act out classroom interactions… in an anticipatory fashion” (Horn, 2005, p.225). Rehearsals involve teachers' narrations and enactments of how they may voice an anticipated practice, and support teachers by creating imaginative spaces in which they try on a practice and then evaluate it with colleagues (Horn, 2010; Horn & Little, 2010). Propositions are statements made between colleagues in which a teacher suggests a course of action as a possibility for the lesson. The group of teachers does not immediately agree or disagree with the inclusion of the action, but instead, they use the proposition to open up a discussion about their interpretations of the action, how it aligns with other parts of the lesson, and how it helps them enact their pedagogical responsibilities around student learning and equity. Teachers use their conceptual resources to analyze the proposition and tailor the action to their unique needs. Analytically, I use these pedagogical propositions to identify a launching point in an episode of a conversation that elicits teachers' reasoning and pedagogical responsibilities. This highlights how teachers apply teaching practices and the conceptual resources they use to adapt the proposal. Such conceptual resources can be used to take up new practices that work towards teachers' goals, or shut down new practices and therefore reinforce prior notions and practices of teaching. Pedagogical propositions don’t point to new and transformative learning, but instead point to episodes of discussion that show how teachers are navigating new concepts within the context of their day-to-day work. This theoretical framework helps me to answer my question about how teachers navigate tensions between their goals and shift toward more equity-focused commitments.

Conceptual Framework

To understand the mechanisms of science teachers' collaborative learning, I drew from literature related to pedagogical judgment in collaborative learning communities, and situated perspectives that point to the ways teachers-as-learners make sense of their goals and move toward more sophisticated approaches (Hayes et al., 2023; Kayumova & Buxton, 2021; Shim & Thompson, 2022). From these theoretical bases, I conceive a model of teacher learning that occurs during teachers' collaborative discussions as they work to align and refine their goals and practices, in light of their evolving resources, contexts, and sense of students' needs (Allen & Heredia, 2021; diSessa, 2006; Horn & Garner, 2022; Lave, 1996). Researchers have found that teachers draw on multiple resources and appropriate them into their conceptual infrastructures (Clarke & Hollingsworth, 2002; Horn & Garner, 2022), such as personal beliefs, curricula, activity structures, school and district messaging, and societal discourses about teaching. Concepts are distributed across people, settings, and activities, and can be investigated through representations of concepts across people and practices (Hall & Jurrow, 2015). Teachers' actions are guided by their understandings of teaching and the goals they hold.

Teachers develop expertise and come to refine their concepts of teaching, the alignment of their professional goals, and their ability to efficiently interpret and act in the classroom, which Anne Edwards (2010) calls a resourceful practice and Rosebery et al. (2016) refer to as interpretive power. Teachers hone their understanding of the connections between their repertoire of practice and their judgments through classroom experiences (Lefstein & Snell, 2013). Whether in the immediate moment of a class full of students or in reflection and retrospection, teachers make decisions about what they notice and how they evaluate those events. What teachers pay attention to and how they interpret that data can depend on how they center equity, language, or other ideologies (Patterson-William et al., 2020; Goodwin, 1994;

Louie, 2018). Teachers integrate these learnings to develop holistic theories of their teaching practice (Korthagen, 2010), which inform discussions with colleagues.

In the course of learning, teachers' pedagogical judgments become more complex as they take a more ecological view of events and ascribe greater value to students' epistemologies (Horn & Garner, 2022; Shim & Thompson, 2022). Teachers may use this learning process to reify or rearticulate their ideologies (Philip, 2011). In addition to moving from knowledge-in-pieces to more internally consistent views, teachers, especially those working collectively, can renegotiate their understandings of race, equity, and their role in moving away from dominant ideologies (Daniel et al., 2023; Burgess & Patterson Williams, 2022; Morales-Doyle et al., 2021).

When examining learning from a situated perspective, researchers look to the changing relationships and interactions that enable the community of practice to generate meaning (Greeno, 2006). This might look like teachers reaching out to colleagues or external school partners for advice and guidance on adopting a new practice (Bridwell-Mitchell et al., 2023), or co-teachers engaging in critical reflection and building a set of shared practices (Eick et al., 2003). Through the lens of cultural changes across educational layers, researchers have examined how traditional teaching practices that align with dominant cultural norms are often reinforced (McKinney de Royston & Nasir, 2017; Burgess & Patterson-Williams, 2022). Novel practices and non-dominant approaches to the classroom must gain legitimacy within their institutions, often involving friction with established norms (Ward et al., 2011). Cultural shifts require time, sustained effort, and support from teachers and school leadership to work through conflict and develop cognitive salience and collective identification (Bryk et al., 2015; Marshall et al., 2021; Holland, 2001). In this study, I hope to illuminate how teachers refine their pedagogical judgments in discussion with colleagues and shift their practices and relationships with the concepts they are learning as they navigate their professional goals.

The conceptual framework for this study draws significantly on the work of Horn and Garner (2022), using their descriptions of episodes of pedagogical judgment in teachers' collaborative discussions. Understanding the pedagogical actions, reasoning, and responsibilities that support teacher learning during collaboration will reveal what supports teachers' learning and how teachers navigate multiple goals. This conceptual framework will help me to answer my three research questions.

Research Question 1: How do teachers wrestle with enacting their stated equity-oriented goals?

Research Question 2: How do teachers collaboratively navigate tensions among their goals?

Research Question 3: How do ambitious project-based instructional units help teachers address equity goals?

In the following chapter, I review the methods I used to organize this study. I then present my findings. Chapter 4 addresses my first research question. Chapter 5 addresses my second research question. Chapter 6 addresses the third research question.

Chapter 3: Methods

In the previous chapter, I reviewed the literature on equity in science education and how goal conflict informs teachers' work. In this chapter, I lay out the methods I used to answer my research questions and describe the theoretical and conceptual foundations of these methodologies. I begin by providing context for this study by describing the settings and participants. I then elaborate on my role in participating with these teachers, along with my ethical research positionality. I then outline the data sources that informed this study. Finally, I describe the three phases of data analysis that helped me to organize my findings in response to my research questions. I end this chapter by discussing how I ensured the trustworthiness of this study and its limitations.

For this study, I conducted a qualitative descriptive case study (Merriam, 1998; Yin, 2014) to investigate the collaborative planning work of a group of science teachers over eight months (See Table 2 for a timeline of data collection, p. 51). The goal of descriptive case studies is to obtain an in-depth understanding of the unfolding events under study in natural, real-life contexts (Crowe et al., 2011). I examined the patterns of talk and interaction during the planning meetings of three biology teachers at a single public high school. As a bounded system, I chose to focus on teachers' collaborative work during planning meetings, while excluding meetings among the full science department or whole-staff meetings at the school. By focusing on the planning meetings, I was able to analyze the teachers' work, which was highly self-directed and directly tied to classroom interactions and student work. These qualitative methods allowed me to study a case of collaborative teacher learning in line with my three research questions.

Setting

This study was conducted during the 2025-26 school year at Echo High School[1], a large public high school in the Pacific Northwest. According to the state report card, Echo High School enrolled 1,100 students in grades 9th through 12th, with 65 teachers, averaging ~9

years of experience. 47% of students identified as Hispanic/Latine, 21% as Asian, 14% as Black, 7% as white, and 2% as Pacific Islander. 71% of students qualified for the free lunch program. Echo High School serves a student population that is 42% English Language Learners. The school is more racially, linguistically, and economically diverse than the surrounding cities in the region, which are ~70% white, ~10% below the federal poverty level, and ~80% primarily English-speaking. The school addressed its demographic diversity through a mission statement that promotes culturally responsive teaching practices, community partnerships, and the celebration of diversity. This is reflected at the district level with a mission promise to know every student by name, strength, and need. Echo High School was an opportune site for studying how teachers held and enacted equity goals (Allen & Penuel, 2015; Hutner et al., 2022).

I collaborated with three 9th-grade biology teachers from Echo High School for this study. While the science department consisted of seven science teachers, the three biology teachers had a unique class schedule with shared prep times that allowed them to meet and collaborate more frequently than the full department could. The biology teachers met for an hour every other week to collaborate on lesson planning and align unit sequencing. These shared planning meetings were the primary site of study for this dissertation, as the teachers worked to establish shared goals and teaching practices to help them achieve them.

Two of the three teachers taught the General Biology courses, with the third teaching biology sections for students across the multilingual learning (ML) program at Echo High School. The ML courses were divided into three sections: Beginner ML, Intermediate ML, and Advanced ML. The school recently adopted the OpenSciEd (2022) curriculum during the 2024-25 school year, and the Biology teachers have worked to adjust their curriculum to better serve their diverse student population. The participating teachers explicitly stated that they wanted to provide equitable teaching experiences and to use culturally responsive practices to support students' learning of meaningful, socially just content. The teachers recognized a need

to translate their curricular resources to better meet the needs of their multilingual teaching contexts.

Participant Profiles

In this section, I provide profiles of each of the three biology teachers who participated in this study. I outline the teacher's background, values, views on equity, and teaching goals. This information came from interviews, planning meeting discussions, and emails in which I asked each teacher to confirm or modify their own profiles. Gender and ethnicity were self-reported by the teachers. In chapter 4, I elaborate on the teachers' collective equity goals using quotes from various data sources.

Hattie is a 9th-grade Biology teacher at Echo High School. Hattie has been teaching high school for 13 years in the Pacific Northwest and has been at Echo for two years. She is the department chair for the science team. She identifies as a Japanese American woman and speaks primarily English. She has a background in biomedical research, received her educational training from the local university, and has held her National Board Certification for 10 years. Aside from the Biology courses, she also teaches a section of Anatomy & Physiology.

In interviews and discussions, Hattie has shared her goals in teaching science. She wants to help her students see that they can be scientists because she never saw her own identity reflected in the science she was taught in school. She also wants to provide a view of science that connects to issues of social justice and shows how society and science interact. She believes that “science doesn’t exist outside of society and that to learn about science in the absence of social issues just paints a 1-dimensional picture.”

Hattie's view of equity reflects her goal of making science accessible to her diverse students. She hopes to meet each student where they are academically and provide scaffolding and support that help them meet the learning goals. She works to structure her class so that every student has an equal opportunity to participate. Hattie recognizes that to accomplish this,

she must use examples and topics relevant to students' lived experiences, which means adapting the curriculum to meet her students' needs and interests.

Hattie has said that her goal for her own learning centers on making sense of curricular resources and adapting them to meet her students' needs. The school has adopted a new curriculum, OpenSciEd (2022), and Hattie is working to understand what materials from that curriculum work with prior activities, resources, and materials she and the school have used in the past. She described this process as requiring deep reflection on what she values in curriculum and teaching, and on refining the lessons to align with those values. She also recognized her areas of growth in teaching, including how to provide language support for her multilingual students and how to respond to students' diverse sensemaking and inquiry.

Erika is a 9th-grade biology and multilingual educator with 15 years of teaching experience, including the last five at Echo High School. In addition to her teaching course load, Erika works as an instructional coach at the school, frequently observing in other classrooms and debriefing through coaching conversations with other teachers. She has presented at various professional teacher organization conferences on topics of social justice and multilingual education. She identifies as an English-speaking American with Japanese and Scandinavian heritage. Erika's courses include Biology for ML Beginners, Biology for ML Intermediates, and Biology for ML Advanced.

Erika shared that her priorities and values as a teacher are focused on developing students' scientific literacy as a project of empowerment. She recognizes that science and scientific literacy can be processes that promote a capitalist view of productivity and progress. She wants to position students to counteract this by providing them with the tools to understand how things work, critique the validity of various claims, and engage with real-world problems. In an interview, she said, "I value justice, social justice, and I am anti-capitalist, and I want to magnify the identities of our students to decolonize our pedagogy in how we frame and teach things." These views align with her definitions of equity. Erika said that equity requires that

people “call into account the structural things that have made it hard for some people and easy for others, lifting up those who have had structural disadvantages.”

Erika has stated that her professional goals center around turning these ideas of equity and justice into the practical work of teaching. Her primary teaching role is as a biology teacher for beginner and intermediate-level multilingual learners. She says she is working on talk strategies with her students, using group roles and discussion routines to support their language use. She allows students to use their heart-language (ie, their preferred language, which may be different than the students' first language or home language) to communicate their ideas and wants to provide her students with rich learning contexts so they can authentically use language or visuals to explore the science ideas and content of her class.

Zach is a 9th-grade biology teacher in his fourth year at Echo High School, with 5 years of teaching overall. Zach received his Master's degree and teaching certificate from a large university in the Pacific Northwest. He has participated in and co-authored research related to equity and student voice for a science education journal. He is a white male teacher and the least experienced teacher on Echo High School’s biology team. Zach also teaches a course of Environmental Science.

When I asked Zach about his priorities as a science teacher and what he values about science, his response focused on creating space for students to explore concepts, lead their own inquiry, and drive the class forward. He stated that he believes “learning should be for everyone, and that the science we are learning should reflect our community, and is relevant to their futures and interests.” He says he wants students to have agency in his class, guiding where the learning goes and following up on their own questions. For Zach, agency comes up in project-based work, where students can direct their efforts toward problems and solutions that interest them.

Equity, in Zach’s view, is when “every student is getting what they need to be successful, even if that means some students are getting more attention and support from [Zach] than

others.” This view demonstrates how Zach works to provide fairer access to learning opportunities that recognize the differences in achievement that students bring to his class. Zach extended this definition to include the topics and content of the class, which he sees as reflecting his students' lives. He wants students’ identities to be reflected in the curriculum and for the learning to be relevant to his students.

Zach has shared that he is working to improve his practice by paying closer attention to how he positions students as active participants in the learning process. He wants to engage students better through active work that gives them the opportunity to be more generative and creative. To do this, he wants students to be able to share their thinking as it develops over the course of a unit or project, use student ideas to guide learning, and also meet the content learning goals. Zach has experience with project-based learning but wants to feature this more in his practice by adopting structured ways to use roles, tools, and accountable talk and collaboration. He hopes to provide more clarity on such routines and also allow students to naturally take them up.

I have summarized these profiles in Table 1.

Table 1. Teacher Profiles

Name	*Teaching Experience*	*Gender and Ethnicity*	*Courses Taught*	*Goals*
Hattie	2y at EHS 13y total	Female Japanese American	General Biology, Anatomy & Physiology	Adapting resources to meet students' needs.
Erika	5y at EHS 15y total	Female Japanese and Scandinavian	ML Biology - Beginner, Intermediate, Advanced.	Language supports making science accessible for ML students.
Zach	4y at EHS 5y total	Male White	General Biology, Environmental Science	Supporting student agency and creativity through generative teaching.

Researcher Role

Over the eight months that I worked with the participating teachers, I positioned myself as a participant-observer of their planning meetings (Gold, 1958; Saldaña, 2011). During recruitment, I sought out a team of teachers who were already working on a project to improve their professional work. As such, I did not enter this study with a pre-established intervention to implement on a group of teachers, nor did I intend to confirm the effectiveness of coaching strategies or professional development support. The three participating teachers invited me into their collaborative work, allowing me to observe the naturalistic ways they organized and oriented themselves to improve their pedagogy to better attend to equity and issues of justice. As a participant, I attended their planning meetings every two weeks (See Table 2) and engaged in discussions about how to set up and run lessons, including reflections and pedagogical judgments that informed those choices. I asked questions such as what the lesson's goal was or how the teachers thought their multilingual students might respond to a set of instructions. I offered feedback on their lessons when asked and used my position as a researcher to analyze both student data and teachers' discourse, providing observations that supported the teachers' reflections. I did not have authority over the teachers and did not direct them on what to do. I frequently offered observations of their work alongside probing questions to create space for collaborative discussion during the planning meetings, but then engaged equally in evaluating which actions should be taken, leaving the final decisions to the teachers.

I engaged with this team of teachers as a partner in the work of learning. As a participant-observer, I observed discussions and lesson-planning work, which helped me understand the points of view and beliefs that drove this group of teachers' work (Dewalt & Dewalt, 2011). As a researcher, during the meetings, I sought data on what teachers stated as their goals, as well as how they worked in their daily practice to enact them. From this situated perspective, I sought to identify actions and concepts taken up within the teachers' community

of practice, to see which goals were being prioritized and how the teachers were organizing their teaching to achieve them. I looked at episodes of pedagogical judgment to see which pedagogical actions were proposed, the pedagogical reasoning they used to support those actions, and how they described how their lessons aligned with their pedagogical responsibilities.

As they engaged in professional learning toward their equity goals, I reflected on my own understanding of equity and science education and used this study to engage as a legitimate partner and fellow teacher in our collaborative learning process. I examined my own positionality and reflected on how I interacted with the teachers in this study through journaling and analytical memos throughout my data collection. In these memos, I considered how my limited window into these teachers' classrooms and planning meetings might lead me to oversimplify their experiences. In response, I reviewed the meeting recordings and my observation notes, seeking to nuance the teachers' actions by identifying the multiple conditions and considerations they were working with. I recorded these possible interpretations as notes and used them during my analysis and during member checks to confirm my understanding of the teacher's work.

Positionality

This dissertation, and all research I engage in, is shaped by who I am, what I know, and what I've experienced. I am a White, heterosexual male. I was raised speaking English in a primarily English-speaking American community. I have been afforded privilege due to a middle-class upbringing and continue to benefit economically and socially from this position. I have not experienced disability beyond temporary injury and acute illness. Each of these identities shapes my position as an educator and researcher. I recognize the similarities between my own identity and the identities of researchers who have engaged in extractive research from marginalized populations, or who have approached their research as experts coming in to save and repair a community. However, by clarifying how I reflect on my own

experiences, privileges, biases, and assumptions, I hope to build my trustworthiness as a researcher.

In this study, which focuses on teachers' learning of more equitable approaches to science education, the teachers echoed much of my own experience learning to teach for equity and justice (Patterson Williams et al., 2020). Therefore, I monitored my assumptions about teachers' learning. My experiences as a teacher and as a learner for equity were not the same as others' experiences. I have reflected on my experiences and have been attentive to how I interpreted the experiences and words of the participating teachers. The teachers have drawn on their unique histories and positionalities as they have made sense of their classroom experiences and learned from one another. In this dissertation, I have reflected on my assumptions about how events unfolded and recognize that they are part of my interpretation process. I shared my interpretations with the participating teachers and sought their interpretations to inform my analysis.

My biases and assumptions are a constant influence on my thinking. Systems of racism and dominance are a part of the context in which I work. The influence of these factors requires sustained attention to recognize and interrupt their impact on my work with others. This is also true for the teachers who participated in this study. While attending to my own biases, I watched and accounted for the ways teachers' biases and assumptions influence how they learn and how they engage in learning with one another. While I provided the participating teachers with grace as they engaged in vulnerable learning spaces with me, I also took a firm stance on my own commitments to the rights, values, and legitimacy of marginalized people affected by this work (Nieto, 2000).

To support the navigation of the essential work of learning and research, I prioritized the relationships I built with the teachers who participated in this study. In this regard, I drew on Moje's (2000) article to attend to power, authority, and goals in this collaborative study between teachers and me. My relationships with these teachers influenced both how I work with them

and the patterns I analyzed in the data as a result of their learning. I accounted for how the teachers may have tailored their responses to me, both positively and negatively. I worked to establish strong, supportive relationships with the teachers based on non-evaluative approaches and open dialogue. I supported their learning and offered each teacher a private debriefing session to discuss any issues that arose during my participation with their team. My role in the teacher's planning meetings was as a co-participant and guest. The teachers invited me into their professional space, not as a director of their learning, but as a participant and witness to their work process. In this role, I engaged in the planning process by offering questions that probed their thinking and helped them to elaborate on their reasoning for taking certain planning actions. I wasn't in a position to tell them what to do or pressure them to take actions I thought would be best. Instead, I offered ideas when they asked for advice, and I offered feedback on patterns I noticed in their work when they gave me consent to do so. My influence was a marginal factor that helped the teachers recenter their goals and highlight their normal habits and meeting routines, but I was not wholly responsible for their growth. The learning and practice shifts demonstrated in this study were the result of the teachers' continuous hard work and drive to better serve their students.

Data Sources

Data was collected and simultaneously analyzed from May 2025 through January 2026. (See Table 2 for a timeline of meetings and observations). At the end of the school year in May, I interviewed teachers and attended two end-of-year planning meetings, which helped me start building relationships with the teachers, identify the professional goals they held, and understand the routines of their planning meetings. As the school year started again in August, I joined their bi-weekly planning meetings and made periodic classroom observations during their first semester, which culminated in a project-based unit on climate change in December. Over

the course of these eight months, I was able to see a trajectory of learning as the teachers worked to enact their equity goals.

Data sources in this study came primarily from video recordings of teachers' planning meetings. Secondary data included semi-structured interviews for each teacher (one initial and two exit interviews), monthly classroom observations of instruction, and artifact collection of student work and teachers' planned lesson materials. The findings of this study primarily draw on the analysis of discussion episodes during teachers' planning meetings. Other data sources, such as classroom observation and artifacts, were helpful to confirm and extend the analysis of teachers' discussion, but were backgrounded in the findings.

Planning Meeting Video Recordings. I recorded videos of 10 of the teachers' biweekly planning meetings that I attended. In addition to audio of teachers' conversations, video allowed me to capture their interactions, gestures, and physical orientations toward one another and toward artifacts, providing insight into the nonverbal components of their discussions (Jordan & Henderson, 1995). The teachers met during their shared prep periods every other week. The primary goal of these meetings was to collaborate on planning for upcoming lessons and unit sequences. The teachers created rough calendars to predict how much time they would spend on the unit and identify the main learning activities they would all use with their students. They made space for each teacher to tailor lesson materials and slides to their unique classes. This structure allowed them to share major learning targets towards which they could build shared practices, while also providing each other space to modify activities and instructional delivery that were responsive to their students and the teacher's communication style. During the planning meetings, I positioned myself as a participant-observer and worked with the teachers to establish norms for how they would like me to support them. The teachers engaged me as a critical friend (Costa & Kallick, 1993) to offer reflections, questions, and ideas that helped inform their planning work. As a participant in this teacher community, I engaged in my own learning about multilingual education, the teacher's curriculum, and how they centered students. The

teachers also frequently made time to discuss the logistics of schoolwork, student behavior, and other relevant problems of practice. They did not follow a strict protocol for their meetings but allowed the time to flow naturally from topic to topic, with each teacher redirecting the group as needed. The planning meeting conversations served as the primary source for my analysis of the teachers' discussions and pedagogical judgment. After each meeting, I created content logs and wrote analytic memos that identified significant segments of talk for transcription (Erickson & Schultz, 1997). As a researcher, I examined and reflected on teachers' discourse, how they oriented themselves to one another, the conceptual resources they drew upon, and how they grappled with implementing new instructional moves.

Interviews. I conducted semi-structured interviews with each teacher, once at the start of the study and twice at the study's conclusion (Crabtree & DiCicco-Bloom, 2006; Merriam & Tisdall, 2009). The interviews were audio-recorded and transcribed. The first interview served to establish a baseline of teachers' conceptions around science teaching, multilingual education, and how they work with their colleagues during PLCs. The participating teachers and I began building relationships during these interviews, which allowed me to support their learning throughout the study. Initial interviews were guided by a semi-structured interview protocol (Appendix A) that was designed to reflect the conceptual frameworks I developed above. I sought information on the context of their work, what they value in science teaching, their views on equity in education broadly, what equity looks like in their biology classes, and the goals they set for themselves professionally (Jones, 2003; Pudelko & Boon, 2014). I also asked what they hoped to gain from partnering in this study and how they wanted to be involved in the analysis and the depiction of the findings. The second set of interviews at the conclusion of the study acted as exit interviews (Morrison et al., 2012, see Appendix B). I returned to the teacher's stated professional goals, confirmed three goal statements that emerged from the teacher's work, and provided space for teachers to extend their thinking in reflection on these goals. I also asked about meaningful moments of work across the study, including the teachers' perceptions

of the final project-based climate change unit, which became a significant part of their learning trajectories. I conducted a second interview after a month's time, as I had analyzed more data. These second sets of questions helped me to confirm findings and claims I make about teachers' learning. The interview served as a closure of our participant-observer relationships, and an invitation to continue the relationship as colleagues and friends.

Classroom Observations and Artifacts. During each unit of instruction from September to December, I observed in teachers' classrooms to document how they were implementing ideas from the planning meetings. This resulted in 10 classroom observations: three from Zach, three from Erika, and four from Hattie (See Table 2 for alignment of observations and instructional units). I used a formal observation protocol (O'Leary, 2020; see Appendix C) and focused on how the teachers were integrating curricular resources, the instruction plans we discussed in prior meetings, and how they worked toward their equity goals with students. I paid close attention, noting the topics and themes developed in the planning meetings and how each teacher enacted those practices. Additionally, I collected artifacts of student work, including photos and copies of the digital presentation slides the teachers used in their lessons. These artifacts were not gathered exhaustively; I selected samples based on teachers' planning discussions to confirm my interpretation of how they planned a lesson. Finally, I compiled and saved email threads with all the teachers, including discussions of goals, summaries of their meetings, and next steps they hoped to take. I used these records as extensions of the teachers' planning meetings, particularly around the goals they were working on, and as member checks on early iterations of my findings.

Table 2. Timeline of Instructional Units, Planning Meetings, and Classroom Observations

Instructional Unit	**Dates of Planning Meetings**	**Episodes of Pedagogical Judgement**	**Classroom Observations**
End of Year Reflections	1. June 3, 2025 2. June 10, 2025	- 4 episodes - 1 episode	

Introduction and Class Routines	3. Sept. 9, 2025	- 6 episodes	Hattie: Sept. 17, 2025 Zach: Sept. 17, 2025
Macromolecules	4. Sept. 23, 2025	- 2 episodes	Hattie: Sept. 29. 2025
Matter and Energy	5. Oct. 7, 2025 6. Oct. 21, 2025	- 8 episodes - 6 episodes	Erika: Nov. 12, 2025 Hattie: Nov. 12, 2025
Climate Change	7. Nov. 4, 2025 8. Dec. 2, 2025 9. Dec. 5, 2025 10. Jan. 13, 2026	- 8 episodes - 10 episodes - 2 episodes 47 total episodes	Zach: Nov. 17, 2025 Erika: Nov. 17, 2025 Hattie: Dec. 10, 2025 Erika: Dec. 10, 2025 Zach: Dec. 10, 2025

Data Analysis

I iteratively analyzed data from interviews, PLC recordings, and classroom observations throughout this study. I used analytical memoing and coding cycles to identify emerging patterns across the data sources. Each research question guided my analysis. To answer my first question about how the teachers wrestle with enacting their stated equity-oriented goals, I compared the goals that emerged from interviews with how the teachers enacted them in their planning meetings and in the lessons I observed. To identify their stated goals, my data came from teachers' responses to interview questions (see Appendices A and B). During the study, I provided drafts of their goals from the initial interview and asked for feedback and verification that I had captured their goals and priorities. To answer my second question about how the teacher navigated tensions between their goals, I developed codes around teachers' pedagogical judgment. I identified teachers' propositions statements during their planning meeting that indicated an attempt to plan in accordance with one of the goals, and I followed the discussions of pedagogical judgment to understand how they navigated the development of the lesson towards or away from that goal. I elaborate on these findings across Chapter 5.

For my third question about how the teachers used a project-based unit to address their equity goals, I used an exemplar case of a unit on climate change that the teachers developed,

and analyzed how they approached that unit differently than in prior unit planning sessions. Insights from my analysis-in-progress helped to inform the cycles of learning that the participating teachers and I engaged in. I used data triangulation across data sources to improve the reliability of my findings by aligning my interpretations and rich descriptions of events and actions.

The analysis in this paper followed a case study approach (Bartlett & Vavrus, 2018), in which I explored in depth teachers' learning, attention to goals, and classroom enactments resulting from planning meetings over the eight months of this study. During this time, I used three phases of analysis to study the teachers' learning as the evolution and deepening of pedagogical judgment and their use of conceptual resources (Horn, 2019). In phase 1, I began my analysis by memoing after each planning meeting, reflecting on a set of analytic questions. For phase 2, I then moved to transcribing episodes of teachers' discussions in which they employed pedagogical judgment. These discussion episodes were transcribed by hand from the meeting recordings. Finally, in phase 3, I used an open coding system to describe processes and outcomes from the episodes of pedagogical judgment, thereby identifying themes and patterns related to my research questions.

Phase 1: Analytic Memoing. To identify the units of analysis as cases, I developed a set of analytic questions (Merriam, 1998) that guided my memoing and the identification of episodes of pedagogical judgment from the planning meetings and tied to classroom observations. These questions helped me identify and define significant moments across the data relevant to my research questions; however, my intent was not to strictly bind each case to include only what these questions identified. The boundaries that these questions established were “temporary and… regularly revised in light of new data that are collected and as a result of emergent analyses” (Bartlett & Vavrus, 2018). Further, these questions helped me establish lines of inquiry across multiple scales of this study, including the grain size of individual actions versus group

decisions, comparative cases among participating teachers, and temporal changes over the study timeline. Here is a sample of questions that I started with:

- What pedagogical judgments do I see? What actions, reasoning, and responsibilities are teachers discussing?
- In what ways are teachers narrating or speaking about students' language and science learning?
- How are teachers relating their classroom practice to their PLC discussions? How do they relate their PLC discussions to their classroom practices?
- What do teachers explicitly state as their reasons for taking an action in the classroom?
- What is implicitly guiding the actions the teachers are discussing?
- What role do conceptual resources play in the teacher's discussion?

The broad strokes that emerged from my analytical memos of the teachers' planning meetings pointed me toward episodes of discussions in which teachers grappled with their professional goals by planning specific classroom activities. As I memoed on these analytic questions, I was able to see emerging tensions between the teachers' stated goals and how those goals were being enacted. This provided a focus for the next phase of my analysis.

Phase 2: Pedagogical Judgment Transcription. Teachers' episodes of pedagogical judgment during their planning meetings were the primary site of inquiry for this study. These collegial conversations revealed teachers' pedagogical reasoning, which informed their pedagogical actions and was supported by their pedagogical responsibilities (Horn, 2019). I used a two-cycle coding approach in this phase, employing deductive coding (Miles et al., 2014) based on the conceptual framework of pedagogical judgment to identify teachers' pedagogical actions, reasoning, and responsibilities raised during planning meetings. These codes helped me identify how teachers exercised pedagogical judgment when organizing their lessons and

units to better meet their professional goals. I compared these codes and the work of planning meetings to the classroom observations to deepen my understanding of the teacher's work. A sample of the codes is shown in Table 3.

As teachers learned in their community of practice, they engaged in questioning, analysis, sharing examples, decision-making, and other actions relevant to shifts in their practice. In reviewing the recorded videos of teachers' planning meetings, I made iterative passes through the videos using interaction analysis practices (Jordan & Henderson, 1995) to build a more robust understanding of how teachers used proposition statements as part of their pedagogical judgment as they planned for upcoming lessons. Most significantly, teachers made proposition statements to describe possible pedagogical actions. These propositions emerged as distinct launching points for teachers' episodes of pedagogical judgment. Over the 10 planning meetings I observed, I identified and transcribed 47 episodes of pedagogical judgment that were initiated by proposition statements. These episodes served as the foundation of my third phase of analysis. For my transcriptions, I used conventions from Ochs (1979), which include symbols for latching talk (=), pauses (s), and nonverbal gestures ((*gesture)).* I emphasized block quotes by bolding segments of speech that I highlighted in my analysis.

Table 3: Preliminary Codes. Codes drawn from the conceptual framework and examples that demonstrate how a turn of talk was coded.

Codes	*Examples*
Action	“Because I’m just like, ‘don’t do that on the computer, paper will be easier than whatever drawing program you find on the computer. I’m going to require it to be hand-drawn.”
Reasoning	“And they might not know the answer, but it might help them think about something else. That’s how I would tell them to do it. I wouldn’t use the word feedback probably.”
Responsibility	“But I think that’s important, right. Like it's important to decide how we are

	going to represent those things even if we don't know what they look like."
Propositions	"What if we flipped it and not do photosynthesis first, but sandwich it between cellular respiration first. Then we could do Obie."
Access	"What I always think about is, like, how can I add an image. Like that's what I learned in my ML certification, like always add images. It helps like everybody."
Sensemaking	"Like, what do these observations mean? How does it connect the data to what we know about cells?"
Justice	"Plants aren't here for the service of people. Yeah, that's another one that would tie into indigenous knowledge."

Phase 3: Patterns and Themes. In this phase, I used a second cycle of coding using an inductive open-coding approach (Saldaña, 2011) to identify patterns and themes across the episodes of pedagogical judgment identified in Phase 2. These codes focused on how teachers moved toward their goals, how they communicated their views on science teaching and equity, and how they worked to resolve conflicts among themselves and among ideas. As patterns emerged, such as which stated goals the teachers prioritized over others, I was able to compare these threads of findings across the 47 episodes of pedagogical judgment to find confirming, contradicting, or alternative patterns in the teachers' work. For example, an initial pattern emerged around teachers' propositions: some were very specific, such as describing the wording of a prompt to be used in an activity, whereas others were much broader, suggesting general actions the teachers wanted to take. I further extended these assertions by comparing them against other data sources, including classroom observations, teachers' artifacts, and the interviews. However, across the episodes of discussion, I did not find that a comparison of specific versus broad propositions was tied to any source of judgment or to teachers' goals, nor did it shape how the teachers enacted their goals. Looking at classroom observation data, the pattern of broad or specific pedagogical actions was no longer observable and didn't appear to affect how the teachers organized their classrooms. Thus, I did not pursue findings along this

theme. By triangulating evidence across my data sources, I strengthened my findings and focused on patterns in the teachers' work that affected how they attended to their goals.

As I analyzed the teachers' planning meetings, I extended my interpretations of the discussions by comparing them to the classroom observations. Memoes from the planning meetings provided me with foci during classroom observations. For example, when a teacher discussed planning for a gallery walk activity, I was initially unsure to what extent this activity was working towards supporting students' agency and sensemaking or if the goal of the activity was to expose students to additional examples of the science content of the lesson. From the classroom observations, I was able to verify how the teacher positioned students in the activity, either by providing them space to discuss the posters around the room or instructing them to record key ideas into their notes without opening the space for students to share their interpretations. My analysis of the planning meeting was supported by data from the classroom observations, as I compared the emerging themes to classroom interactions and teaching enactments.

Trustworthiness and member checks

Over the course of the study, I engaged the participating teachers in member checks through one-on-one debriefing conversations after classroom observations and email discussions after planning meetings (Lincoln & Guba, 1986). In these member checks, I shared my memos and my thinking about initial patterns in the data to determine whether my analysis captured the teachers' experiences and understandings. Through email exchanges and conversations, I was able to confirm a set of goal statements that guided the organization of my findings in Chapter 4. Over the course of the study, I also conducted informal conversations with science education researchers and teachers outside of the study, in which I shared anonymized examples of teachers' work along with my interpretations of the planning meeting discussions to confirm or disconfirm my findings. This work helped me examine my biases in understanding the

teacher's work and to draw more robust conclusions from the data. I improved the trustworthiness of my interpretations through the input and evaluations of others who supported my work throughout this study.

Limitations

This study was limited in scope by deliberate choice. By focusing on one group of science teachers who frequently collaborated during their lesson-planning periods, I was able to provide a detailed description of the processes and experiences that led them to attend to their professional goals. A separate set of teachers may have held different equity goals and thus worked across different trajectories, making comparisons less informative. Further, this study did not span a full school year. I limited my data collection to one semester, including the initial month. This first month allowed me to observe teachers' end-of-year reflections and goal-setting for the next school year, along with the initiation of relationship-building. In the following semester, I was able to follow how those goals were being implemented, concluding in a unit of instruction, the project-based climate change unit, that made explicit space for the teachers to work towards their goals. This study's relatively small number of participating teachers and a delimited timeline allowed for a close examination of teachers' learning in the context of their daily teaching practice. The findings are not intended to directly transfer to all contexts and schools, but serve as a case showing how teachers navigate tensions between goals and the work of teaching.

The analysis of this research was done solely by me, as the participant-observer and author of this dissertation. In this capacity, the findings inherently reflect my own interpretations of events. While I used codes drawn from the literature I reviewed earlier, my own biases and limitations influence the findings I explore in the next three chapters. This reduces the generalizability of the findings but continues to illustrate teachers' experiences within the cited body of literature.

In the next three chapters, I present my findings for each of my three research questions. In Chapter 4, I show what the participating teachers stated their equity goals were and how they worked to enact them during the planning meetings. In Chapter 5, I discuss the tensions that arose when teachers' stated goals conflicted with the patterns of planning and enactment, including how their work to resolve those tensions often led to the prioritization of one goal over others. Finally, in Chapter 6, I demonstrate how the teachers worked to enact all three of their equity goals during the planning and implementation of their project-based climate change unit.

Notes

1. Pseudonyms were used for the school, district, teachers, students, and place names. Data was taken from public records and rounded to preserve anonymity.

Chapter 4: Teachers' equity goals.

In this chapter, I provide an account of the goals that the teachers and I developed over the course of the study, and an analysis of how these goals were implemented during the teachers' lesson-planning work. This chapter provides evidence for my Research Question 1: How do teachers wrestle with enacting their stated equity-oriented goals? I start by describing the process of developing three goal statements that the teachers agreed upon. I next elaborate on each goal, using examples from the teachers to clarify how they conceptualized each goal. I also include an analysis of how teachers' statements about their goals compare with how they worked toward them during planning meetings and in the classroom lessons I observed. Lastly, I provide an example of how a complex aspect of teachers' work, specifically that of relevance, was used to work towards all three goals, while also leading to implicit assumptions about how planning work served each goal.

Comparing stated goals to enacted practices

Over the course of this study, the teachers and I engaged in discussion and reflective talk to develop goals for improving their instructional approaches; however, the multiple goals often conflicted as they attempted to design lessons and activities. Each of the teacher's goals addressed student equity in learning science through different aspects and approaches to equity and justice. The teachers wanted to ensure clarity in their instruction to provide their diverse students with access to learning opportunities. They also wanted to organize their lessons so students could make sense of scientific phenomena. And the teachers hoped to link the science content to issues of justice that were relevant to the students' lives. Over the course of interviews, emails, and researcher check-ins during the planning meetings, we collectively created the following three goal statements:

Echo High School Biology Teachers' Goals

1) **Access to science content:** We want every student to be able to achieve the science content learning objectives. To do this, we must provide instruction that is clear, accessible, and engaging.
2) **Support sensemaking:** We want to support students' sensemaking skills by providing learning opportunities that cultivate creativity, agency, and the ability to explain scientific phenomena.
3) **Link science to issues of justice:** We want to present science in ways that are relevant to the contexts of our students' lives, connected to societal issues, and inclusive of diverse perspectives and ways of knowing.

These goals were supported by the teacher's statements across the interviews and check-ins, which helped clarify the goals and demonstrated the breadth of teaching practices the teachers linked to them. In the section below, I explore data that demonstrates how the teachers viewed these goals and what their planning looked like as they worked toward them.

Goal 1: Access to science content

The teachers stated that they wanted every student to have a rich learning experience by providing students with clear, direct, and engaging lessons. To this end, they wanted to improve their language support for their multilingual learners so they could access science content. Hattie described her way of working towards equity as "giving students resources in a way that meets kids where they are." She provided an example, stating that while her "beginning ML(multilingual) students and Gen Ed students have the same content standards, the scaffolds that I have to put in are different." She went on to explain how she's still learning how to provide instruction that helps both groups to learn. She described how she struggles to balance content standards with language standards, saying, "I always go in the way of teaching more science and less language, which is probably not what I should be doing." The teachers

recognized they needed to improve their practice by paying closer attention to students' language needs. They also wanted to provide instruction that centered on the learning needs of their students who are struggling the most in school. Zach described his process of attending to equity as making sure “every student is getting what they need to be successful, even if that means some students are getting more attention and support from me than others.” The teachers wanted to ensure their instruction was tailored to their students' learning needs by providing accessible scaffolding and content instruction.

In their enacted practices during planning meetings and in the lessons they planned, the teachers focused on instructional moves that would support their multilingual students' language development, helping students better access the science content. The teachers created learning structures designed specifically for students who were currently struggling in their classes or who had typically struggled in school. In planning meeting 6, when discussing how students would do a modeling activity, the teachers wondered what language supports their ML students would need. Zach said, “I’m less concerned with putting vocabulary in a word bank, and more concerned with process language, ‘if this, then that,’ like sequential stuff that we always talk about.” In planning meeting 9, Erika proposed having a speaking option for some of their struggling students. She reasoned that “then my students could use the TPR that I did with them. ‘Alive ATP, Alive ATP ((*does hand motion))* Food is Glucose ((*does new hand motion*))’” Erika wanted to make space for students to use the Total Physical Response (TPR) strategies she taught and shared that her students remember those phrases the best. While the teachers named one specific group, their multilingual students, that they centered in their planning work, they often did not name any other group of students they planned to support. The diverse identities and cultures of students were not explicitly named or addressed in a specific way in the data I collected. Instead, I observed the teachers focus on providing scaffolds and accommodations for ‘struggling students’ while leaving implicit who these students were or what systemic barriers might be causing them to struggle.

To create opportunities for students to engage in science practices, the teachers worked to understand the curricular resources provided to them and adapted them into lessons and activities relevant to their diverse students' lived experiences. Zach described his view that “learning is for everybody,… so the science we are learning must reflect our community,” emphasizing that he prioritized relevance so his students could access the learning. He described that he is “figuring out, with the curriculum that we are given, how the students will see themselves reflected in what we are teaching, being relevant to their lives, and using language that is decolonial.” Zach described his teaching practice as still developing, becoming more relevant and representative of his desire to teach in alignment with his decolonial ideals. He saw that his work in adapting the curriculum was essential for providing his students with access by bringing it to them. Similarly, Hattie described her view of equity as involving “giving all students an equal opportunity to participate… by providing relevant topics that we adapt from the curriculum.” She described how her work often focuses on figuring out how to “make the content as clear as possible, so students can follow it and make sense of it.” When focusing on content clarity, Hattie prioritized developing her ability to communicate content objectives clearly to her students.

The teachers prioritized their goal of providing students with access to science content learning during every planning meeting. The teachers foregrounded their reasoning about science content and their plans for delivering instruction to their students in the clearest way. During a discussion in planning meeting 5 around which phenomenon they wanted to use to teach photosynthesis and cellular respiration, Erika said, “I love the plants being grown in the dark, and why they grow taller. The kids love it, and they think it’s inaccurate.” Erika proposed a discrepant event to hook students' attention. Hattie countered this proposal, reasoning and pointing out that the phenomenon is more focused on germination than photosynthesis. Erika agreed, saying, “Yeah, because they are using the sugar in the seeds to grow, so it's not photosynthesis, it's more just cellular respiration.” Conversations like this, in which teachers

discussed the science concepts that they were attending to, made up a significant portion of meeting time. Erika justified spending time with these discussions, saying, “I really want to understand what is happening before, because if I don’t really understand it, I will have a hard time, like teaching it.” She expressed how her ability to teach, and therefore students' access to science content, relied on her own understanding of the science concepts.

In addition to focusing on content learning objectives, the teachers focused on instructional techniques that were most clear to students, often involving direct instruction that replaced sensemaking conversations. When discussing how they wanted to organize their photosynthesis unit during planning meeting 5, Erika said, “I feel like, ditch the phenomenon and just teach photosynthesis… We can still bring up the ‘Plants don’t need people, but people need plants’ but then just say it as an example instead of a phenomenon.” I attempted to point out that by moving away from a phenomenon, the teachers were replacing students' opportunity to struggle and make sense of a concept with direct instruction in which the teacher just tells them the answer. Erika replied, “I don’t think there’s anything wrong with that. I have found you need to directly teach things, and then you can have the activities.” This belief was at the core of Erika’s sense of responsibility in teaching, that she must provide students with access to the science content, and then later engage in activities that help students to remember, recall, and apply those concepts. While the other two teachers did not explicitly state it, all three planned lessons that prioritized clear, accessible content instruction, while sensemaking opportunities were left implicit or in the periphery of their plans. In a moment of reflection, Hattie recognized this tendency to focus more on science content when she considered her approach to language supports. Hattie said, “I never did enough English support, like it was always too much science, so that is something I would like to fix.” While Hattie acknowledged this area of growth, the complexities of teaching and attending to multiple goals led her to background goals beyond supporting students' access to science.

Goal 2: Supporting Sensemaking

The teachers in this study set another goal around sensemaking, stating that they wanted to cultivate students to be more active and creative participants in the sensemaking process. To achieve this, they wanted students to share their thinking using their full linguistic repertoires and funds of knowledge to understand scientific concepts and explain phenomena. Erika shared that one of her personal priorities is to improve her use of “talk strategies like group roles and figuring out how to set up discussions.” She wanted to create space for students to discuss their ideas and use structures that facilitate sharing. This extends to how she supports her multilingual students by allowing them to “talk in whatever their heart language is to talk through the how and why of science, with visuals and hands-on things that they can point to if they don’t know the science word.” Erika embraced students' full linguistic repertoires and was continuing to learn how to support sensemaking that built on students' linguistic strengths. Zach also spoke about his goal of positioning students as active participants. He said, “I value student agency and want to allow for more students to direct where the learning goes. I want students to be more generative.” Zach described how he works toward this goal through project-based learning. He said that there was one unit, a climate change project, where he had good student agency, but wanted to have more units across the year where this was also true. He described how he wants to “have more student project collaboration in a structured way, using complex instruction, roles, and clear routines for how students talk about things.” Zach wanted to create space for students to explore concepts, lead their own inquiries, and drive the class's progression. He stated that he believes “learning should be for everyone, and that the science we are learning should reflect our community, and is relevant to their futures and interests.” He said he wants students to have agency in his class to guide where learning goes and to follow up on their own questions to maintain students' connections between their lives

and science learning. By focusing on students' interests and creativity, the teachers sought to center students' ideas and sensemaking in their science classrooms.

The teachers' planning meetings and lessons demonstrated how they organized their lessons around student agency through inquiry practices. Many of the teachers' episodes of pedagogical judgment involved attention to students' heterogeneous sensemaking. The teachers shared various strategies they used or hoped to use in order to elicit students' ideas in class, such as pair A/B partner talk, class circle discussions, socratic seminars, and observation charts. In these various activities, they wanted to make space for students to discuss with each other or share their ideas with the whole class and the teacher. However, the purpose of that sharing reveals how the teachers viewed the values of their students' sensemaking. In one example, during planning meeting 7, they wanted to use a Slow Reveal Graph routine to structure students' sensemaking around climate change graphs. Erika proposed putting “each graph on a poster paper, and then students can walk around the observation charts and write their ideas below. Then you can review what they are all thinking.” While it was not clear in the meeting if Erika meant review as something the whole class would do together as a process of sensemaking, or something that she would do for herself as a form of assessment, I had the opportunity to observe this lesson in Hattie’s class. After students added their thinking to the charts, Hattie collected the posters without discussing the students' ideas and moved on to an activity in which students worked individually. Instead of using students' sensemaking as a resource for future learning, she reviewed the ideas as a formative assessment of students' understanding of the taught content. Examples from teachers' planning meetings showed they grappled with students' sensemaking but were unsure how to use students' ideas as key features of classroom learning. In the following example, during planning meeting 6, the three teachers were discussing how to use a driving question board to organize a lesson by featuring students' questions.

1	Hattie	You could also ask them for more questions they still have, to add to the class model
2	Zach	Yeah, where do we go next? **Force the agency. I love trying that. I've never done= it successfully**
3	Erika	Yeah, =never have it be successful.
4	Hattie	I tried it on a whole bunch of things last year.
5	Zach	But **I've spent years of work trying to figure out that**
6	Erika	Well, the problem is that every class, like when I did that, when I taught my two chemistry classes, like **I had to do totally different units, so it was a lot of work, like these kids were like 'I want to study this thing' so I ended up, just like, each class was different**
7	Zach	Yeah, it's giving them the illusion of choice
8	Erika	But I gave them actual choice, and I was like, well fuck, now they are doing different things.
9	Hattie	Actual choice is a lot to manage with multiple classes.

Hattie initially proposed asking students for questions, which Zach saw as working toward his goal of promoting student agency. However, they then went on to reason about how difficult it was to use student ideas and questions to drive the class, a practice many teachers find challenging. They shared that they had attempted to organize lessons this way but had failed. They did not know how to structure learning to account for students' heterogeneous questions and sensemaking. Without ongoing systems of support for professional learning on this practice, the teachers struggled to shift their pedagogy to achieve this outcome. Therefore, despite having explicitly stated goals to provide students with choice, they organized their lessons to move away from student agency, instead prioritizing their first goal of providing students with clear, accessible content instruction.

Goal 3: Link science to issues of justice

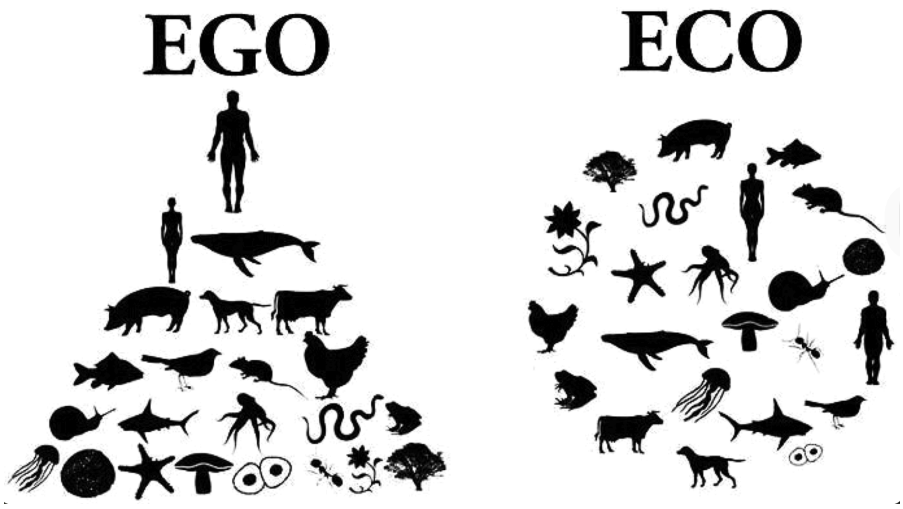
The teachers stated a goal to present science as relevant, connected to societal issues, and inclusive of diverse perspectives. The teachers wanted to present science as connected to human society. Hattie wanted to provide a view of science that is connected to issues of social justice and to show how society and science interact. She believed that “science doesn’t exist outside of society and that to learn about science in the absence of social issues just paints a one-dimensional picture.” Similarly, Erika viewed equity in science as requiring that people “call into account the structural things that have made it hard for some people and easy for others, lifting up those who have had structural disadvantages.” Hattie and Erika wanted to improve their ability to paint a robust, interconnected picture of science content and how people use science in both helpful and harmful ways, speaking to the larger context and systems of science and science education. Erika said she focused on developing students' scientific literacy as a project of empowerment. Zach addressed this issue through his work promoting student agency in project-based learning. He wanted students to be able to “direct their work towards problems and solutions that are relevant to their lives and that they are interested in.” These goals point to how the teachers wanted to provide their students with the tools of science as a part of social justice, so that they could address issues and structural harms in society that impact their students’ communities.

The purpose of this goal extended to the teacher's desire to critique the role science plays in reproducing social harm while producing sustainable cultural and environmental futures. Erika pointed to how science and scientific literacy in education are often used to promote a capitalist view of productivity and progress. She said, “I want my students to use science to be productive citizens, but not in a capitalist sense, but being able to understand how things work, avoid bullshit, and counteract what's valid and not.” In my interview with her, she described how this aligned with her own identity, saying, “I value justice, social justice, and I am anti-capitalist,

and I want to magnify the identities of our students to decolonize our pedagogy in how we frame and teach things." Poignantly, she also recognized that she is still working on turning these ideas of equity and justice into the practical work of teaching, an issue that science education researchers and teacher educators are grappling with as well. What does it mean to decolonize pedagogy? What does that look like in day-to-day practice? These are essential questions that teachers grapple with as they work on making lessons, grading papers, and fulfilling the professional requirements of teaching.

Unlike the other two goals, the teachers' planning meetings rarely prioritized their goal of linking science to issues of social justice. The teachers would often start to plan a lesson with justice in mind, but then minimize those components of the lesson. Across multiple planning meetings and units, the teachers linked content to indigenous histories, knowledge, and perspectives, and considered ways to center these ideas in their lessons. They launched one unit on macromolecules by having students read an article about how Native American diets have changed since European colonization. In another unit, they discussed ways to connect cellular respiration to indigenous perspectives of the interconnectedness of organisms across an ecosystem. They noticed students held a common misconception that plants don't do cellular respiration. Students would often describe plants as only making oxygen for people, and Erika said, "plants aren't here for the service of people… which would tie into indigenous knowledge with the picture of human-centered versus ecosystem-centered views of the world." (See Figure 2) This topic of how plants have complex interdependent relationships in nature was discussed as coming from indigenous perspectives of science, which the teachers wanted to include to combat Western-centric views. However, the teachers struggled to figure out how to present this information to students, returning to the idea across four planning meetings without settling on an actionable plan.

Figure 2. Ego-Eco diagram of humankind as part of the ecosystem, not apart from or above it. (Adapted from Lehmann, 2023)



While the teachers' second goal was to attend to students' sensemaking, their third goal attended to diverse ways of knowing and heterogeneous perspectives from across society. This idea emerged multiple times in the teachers' planning meetings. As I described above, the teachers organized a lesson around the impact of colonialism on Native American diets and discussed how to include indigenous perspectives on the interdependence of plants as more-than-human relations. During planning meeting 7, as the teachers discussed their unit on climate change, they planned for students to read a speech to the UN by an indigenous activist from the South Pacific. Erika said, “I’m looking at this speech, and it's talking about the importance of how we respect nature, but also it's a direct challenge to Western nations and their notion of how we extract resources.” Erika highlighted how the speech was promoting views that were not typically included in Western depictions of science. She wanted this to be an important part of her lesson for students and worked during planning meetings to include these issues in the teachers' lessons while addressing entangled issues across science, politics, and society. These examples show that the teachers considered diverse perspectives a couple of times in their planning meetings; however, these perspectives were not frequent themes, as

other goals took priority. The teachers did not frequently center heterogeneous perspectives from across society as a foundation for the content they included in their lessons, but instead worked to ensure their students had access to relevant examples and clear science instruction.

Alignment of Goals with Frames of Equity

The three goals the teachers established align with the five equity frames described in the Equity in K-12 STEM Education Report (NASEM, 2025). The teachers' first goal was about access to science content. In the teacher's early framing of this goal, they cited the needs of their multilingual students and how they work to support students' learning so everyone can be successful. This goal was driven by a desire to reduce the achievement gap that existed between their general education students and their multilingual student populations, which aligns with Frame 1: *Reducing Gaps Between Groups*. The teacher's access goal was also driven by a desire to provide all their students with rigorous science learning opportunities by making their curriculum engaging to hook students into learning activities, aligning with Frame 2: *Expanding Opportunity and Access*. The teachers' second goal was to support sensemaking. The teachers worked to structure their units to feature a central phenomenon that illustrated a science topic and to organize learning activities so that students would progressively build an explanation of that phenomenon by applying multiple science concepts and generating different explanations, which aligned with Frame 3: *Embracing Heterogeneity in STEM Classrooms.* The teachers' final goal was to link science to issues of justice, which aligned with Frames 4 and 5: *Learning and Using STEM to Promote Justice* and *Envisioning Sustainable Futures Through STEM*. Additionally, the teacher's three goals can be examined through the lens of various approaches to equity in science education outlined by Lee and Grapin (2025). The teacher's goal of access aligns with the traditional approaches to science education, the goal of sensemaking aligns with contemporary approaches, and the goal of linking science to issues of justice aligns with the proposed future approaches.

The Intersection of Goals, Using the Example of Relevance

Certain aspects of teaching, such as how these teachers provided relevant instruction for their students, intersected, overlapped, and occasionally conflicted with the teachers' three goals. One example of this is how the teachers grappled with and applied their concept of relevance to lessons and the curriculum. The concept of relevance was raised in connection with each of the three goals above. In my interviews with the teachers, they stated that they wanted their lessons to be relevant to their students. Zach said, “I want my lessons to be relevant for students and relevant to their lives.” Similarly, in an interview, Hattie said she was revising lessons she previously taught because “they just are so relevant for students. I want it to be connected to their immediate situations.” In these statements, it is unclear how relevance helps the teachers work towards their goals, as I didn’t ask them to expand on what ‘relevant for students’ meant. Through the following examples, I explore the different ways relevance was used.

Relevance was used to provide a hook of interest for students, giving them a reason to continue engaging with science content and thus furthering the goal of making science content accessible. In this example from planning meeting 5, Erika argued for the inclusion of a phenomenon involving a pea that a man had inhaled and then sprouted in the absence of light. The unit was about the cycling of carbon and the processes of cellular respiration and photosynthesis.

10	Zach	So would the “Pea in the Lung’ be good? It's sort of like the mass of the plant example, where does the mass of the plant come from?
11	Hattie	It’s a good phenomenon.
12	Erika	It’s a **really good, relevant phenomenon. The kids are fascinated by**

		it. They are like, 'what the hell?' and the guy in that video is kind of funny, like, 'huh, it just grew there'. But could you say, like "Could the plant keep growing? Does the plant need the person to grow?" I don't know.
13	Hattie	Well, that might be an idea, knowing we are heading toward a climate unit anyway. Or we could have a phenomenon related to carbon levels.
14	Zach	Oh right, the video of a change in carbon each day and like the seasons. There are little fluctuations and then the bigger yearly trends.
15	Matt	And you still have space to bring in Pea in the Lung as like an investigation of how a plant grows without light, producing CO2, and you could get into that as a piece of the larger carbon cycling.
16	Erika	(4) I just don't know if that is a phenomenon that kids like. And being like, 'Look at this carbon cycle'. **It's not interesting. I feel like it's like the wildebeest thing, like who cares? Do kids care about that? It's not interesting.** I like a phenomenon where kids are like, "What the hell?" They love the pea in the lung because it's like, so weird. They engage with it, I find.

Erika described how, from her experience, students showed engagement with phenomena that were weird, unexpected, and funny. She described the 'pea in the lung' example as one that students liked, and would therefore be motivated to engage with as she taught the science that explained the phenomenon. The relevance lay in students feeling hooked or engaged by the example's weirdness. She described other phenomena, such as the carbon cycle, as something the students didn't care about. Relevance was not being used to claim that students would be better at making sense of the phenomenon. In the episode above, Erika also pushed back against the climate cycle example, which was more consequential and

related to the larger issue of climate change but less interesting to students. In this discussion, Erika used the term 'relevance' to refer to an example that would motivate students to engage with science content.

The teachers occasionally discussed relevant phenomena that students could make sense of using their funds of knowledge and prior experiences, thus supporting their goal of improving students' sensemaking skills. During a goal reflection activity in planning meeting 10, I asked the teachers to draw connecting lines between topics I had pulled from discussions over the previous months (See Appendix D: Goal Reflection). Hattie described a connection she drew:

> We are doing a lot of modeling right now in our current unit, so I connected together modeling, and relevance, and authentic because that is the sort of thing that scientists need to do. Like to be able to help students to see how to connect science to real problems."

Hattie saw that the scientific practice of modeling was connected to how scientists engaged with real-world problems and worked to make sense of them. In this example, she used relevance to describe how people use modeling and sensemaking in real contexts. In the third planning meeting, the teachers were discussing a lesson activity in which they asked students to evaluate unprocessed versus ultra-processed foods. Zach had suggested a modeling activity in which students compared the way two different foods would be digested.

17	Hattie	I like that. **That's the real work of figuring out, like, how digestion works in a realistic way**.
18	Zach	Its like the issues that students are thinking about, like how eating an apple or eating Takis is going to make you feel.
19	Hattie	So how should we set it up?
20	Zach	**We have to, like, give them space to write their ideas, maybe let**

		them choose what foods they are going to have on each side. Like, what are they eating every day.
21	Erika	So it's more relevant for them, definitely. I always like showing images, maybe, that they can draw from.

In this episode, Erika realized the example they were discussing was relevant to students. The teachers designed this activity to make space for students to draw on their funds of knowledge and prior experiences to add details to a model of how foods are digested. In this sensemaking activity, the teachers supported students in linking science concepts to the knowledge they already possessed.

Relevance was also used to demonstrate how science can help students apply their knowledge to local, meaningful issues in their community. During planning meeting 7, as the team discussed how they wanted to organize a lesson in which students read a speech from an indigenous climate activist to the UN, the relevance of the reading came up when I asked them what they hoped students would get from it.

22	Zach	It kind of gives them a jumping off point for their projects. They come up with a problem statement, and then they have to solve that problem, basically.
23	Matt	Oh, right, because they are doing something at the neighborhood level. This is branching into that?
24	Zach	Yeah, and that's what, that's why I (3) yeah ((*sighs*)) **that's why I think we should just change this to be more relevant.** Only be about stuff here.
25	Erika	We can, I'm sure there are some indigenous people that have talked about stuff here?
26	Zach	There are.

27	Erika	So why don't we just use theirs? This UN one could be an example, and **then we get a speech from someone who is indigenous to the PNW**. There's been a lot that's changed, like in San Juans.
28	Hattie	We could frame the UN one like, here's someone who's talking about their local climate change problem, and you are using this as a model for how you are going to talk about your local climate change problem.

Relevance was used here to describe a local example in the students' area, helping them attend to problems in their local communities that they could address in their project. This was a change from the previous version of the lesson, which featured a speech by someone from the South Pacific Islands. By moving to a more local focus, the teacher wanted to link the science content they were teaching to issues students could act on in their local community. By emphasizing relevant applications and examples, they were creating space for students to make more meaningful, relevant connections, thus serving their goals of having a justice-oriented classroom.

Throughout these examples, I show how a single concept, like relevance, was used by the teachers in the service of each of their three goals. On the one hand, this demonstrates how a complex concept can support teachers in working towards multiple goals simultaneously. On the other hand, however, this shows how relevance can be used as a shorthand justification for pedagogical reasoning. By citing relevance, the teachers terminate further reasoning, leaving their understanding tacit and possibly different between the teachers. In these instances, they may be working towards different goals. In line 12 above, Erika cites a relevant phenomenon. Zach could have hypothetically interpreted this as meaning either a good phenomenon that students could make sense of or a phenomenon connected to some larger social issue. Erika meant that the phenomenon was effective at engaging students, keeping them motivated, as she taught about the process of cellular respiration during seed germination. The multiple

definitions and uses of relevance created an ambiguous space where one teacher could be offering a proposition of including a relevant example, while the others might interpret that example as serving a different goal. One teacher might prioritize access to clear science instruction, while the other might be viewing the lesson they are planning as a sensemaking opportunity in which productive uncertainty is the goal (Manz, 2018). These differences in interpretation result in teachers offering ideas for organizing a lesson with different goals in mind, while thinking they are aligned in their aims.

While teachers named and agreed on goals they held and worked towards, the practical work of teaching, planning, and collaborating with colleagues was much more complex, with concepts and goals often held more implicitly. This resulted in their work often prioritizing one goal over another, or teachers working simultaneously to design lessons that served different goals. Their stated goals were not explicitly stated or consistently reminded of during each meeting. As they planned, they did not review their goals as a routine to ensure alignment with their commitments. Instead, teachers' goals were held implicitly. As teachers developed lesson materials, they attended to numerous criteria, constraints, and resources that obscured their work from their goals. I examined teachers' discussions as episodes of pedagogical judgment to understand how they conceived their goals and which goals they prioritized.

The teachers stated three goals they felt would help them work towards more equitable classrooms. They wanted to provide all their students with access to science content. They wanted to design opportunities for students to engage in diverse sensemaking around science phenomena. And they wanted to provide students with science instruction that was linked to issues of justice. However, gaps emerged as the teachers moved toward enacting these goals. The teachers felt strongly that science content knowledge was a prerequisite to other forms of learning and thus prioritized accessible instruction. Relevance was used to hook students into the instruction, but was less frequently used to link students' lives to relevant issues of justice. When designing opportunities for students' sensemaking, the teachers began with activities that

elicited ideas, but were unsure how to facilitate those conversations toward sensemaking or to use students' ideas to guide subsequent lessons. The teachers' goal of providing clear and accessible directions and instruction took priority, minimizing their ability to work on the goals of sensemaking and linking science to justice. In the next chapter, I will explore how the teachers grappled with these gaps and conflicts between their goals.

Chapter 5: Navigating Tensions

In this chapter, I present data that addresses the following research question: How do teachers collaboratively navigate tensions among their goals? In the previous chapter, I demonstrated that despite stated goals around three topics: access to the science content, sensemaking, and linking science to issues of justice, the teachers often prioritized their goal of providing clear and accessible instruction. In this chapter, I describe episodes of talk that show how teachers navigated the tensions and conflicts among their goals. One conflict emerged between wanting to ease access to science instruction and wanting to provide a space for productive uncertainty and sensemaking. While there seems to be an inherent conflict between providing clarity and allowing for productive uncertainty (Manz, 2018), the lesson context the teachers discuss offers space for how they could attend to both goals. Another tension emerged as teachers grappled with instructional moves they were less familiar with, such as facilitating whole-class discussions and creating space for students to creatively solve problems. When faced with the possibility of trying unfamiliar instructional moves, the teachers often settled into more familiar pedagogical grounds.

In this chapter, I show how the teachers use proposition statements that explore pedagogical actions in line with their goals of sensemaking and justice, and how their episodes of pedagogical judgment lead them to use their goal of access to justify not attending to the issue of justice or provide space for students to engage in diverse sensemaking. I illustrate how the teachers made pedagogical propositions that foregrounded students' sensemaking, yet then organized the lesson to prioritize students' ease of access to science content. I begin by exploring how the teachers navigated student uncertainty while prioritizing access. I then analyze episodes of discussion in which the teachers navigate unfamiliar teaching practices, only to return to more familiar and traditional ones. Finally, I end with examples that show how

the teachers' concepts of sensemaking and justice tended to avoid students' agency as a learning mechanism.

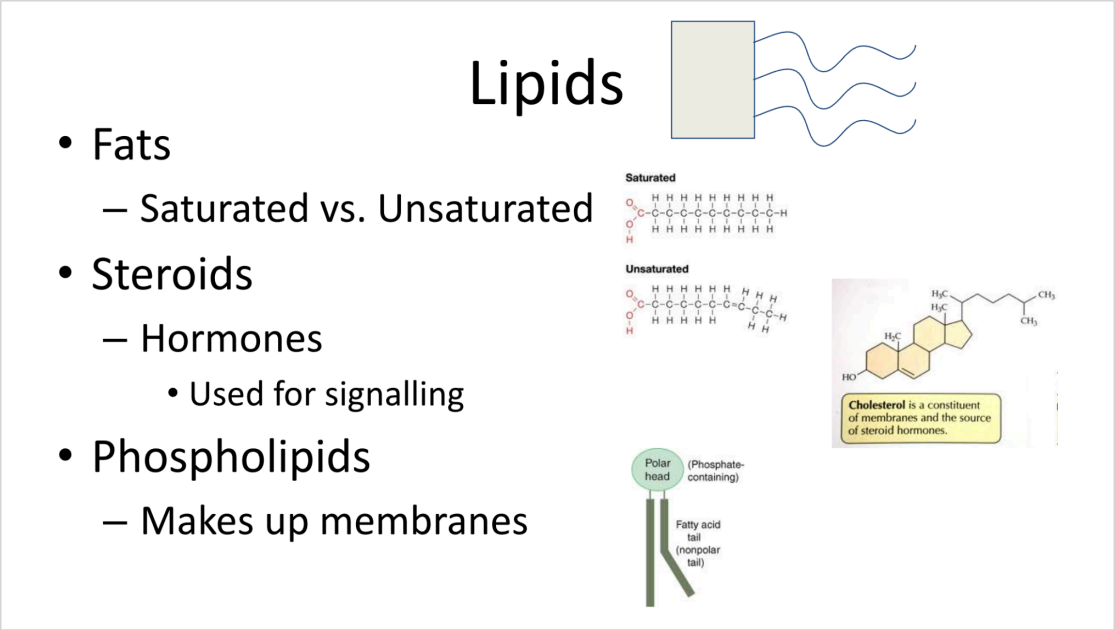
Navigating Student Uncertainty While Prioritizing Access

The teachers proposed practices that pointed towards goals of embracing heterogeneity, connecting to issues of social justice, or attending to sustainable futures, but, through their discussion, often focused on how to provide students with access to science content. In this episode of talk in planning meeting 1, the teachers reflected on their work from the prior school year and discussed what they wanted to improve upon for the next year.

1	Erika	**I would like to do more talk strategies next year,** and more speaking.
2	Hattie	Just like ones you do consistently, like throughout the year. **Like A/B partner stuff?** (2) And like thinking about Gen Ed classes, like that's something= we could structure more. Cause I'm like "None of you are beginners, and a lot of you need more supports"
3	Zach	=yeah
4	Erika	What I always think about is, like, how can I add an image? Like, that's what I learned in my ML certification, like always add images. It helps like everybody.
5	Zach	**Just talking about it too, like, having them talk about the images** (4)
6	Matt	Do you mean just like talking about images, they are explaining their notebooks specifically, or just like images you are teaching with?
7	Erika	Um, **like on presentations, anything, like reducing the text and increasing the image counts**

Erika initially proposed organizing lessons to better promote more student talk. To this proposition, Hattie added clarification in line 2, citing a strategy she believed would support all of her students. Such ‘talk strategies’ could be a helpful way to make space in the class for students to share their thinking and collaborate on sensemaking of science content, especially when designed for multilingual students to use as a bridge between linguistic repertoires and concepts they are learning. Erika then modified the idea to focus on images that she adds to her lesson presentations. While not directly contradicting the purpose of talk strategies as a way to elicit student ideas, adding images without providing space for students to make sense of words, images, and science concepts limits students' learning. In this episode, Erika focused more on reducing the text for students to process, while not attending to students' sensemaking. In line 5, Zach attempted to return the practice to its original goal of student talk. I asked how they are using images to support student talk to see whether the talk was focused on student sensemaking or was a prompt for students to repeat definitions back to the teacher verbally. Erika’s response in line 7 shows that she was more focused on which teaching materials she was adding images to (See Figure 3), without discussing how students would grapple with them. While adding images and supporting student talk could broaden the diverse ways and languages students use to make sense, Erika remained focused on how best to show the science content. The conversation then shifted to a different topic, and we did not continue discussing how students would use images to support their talk. While Zach and I, in lines 5 and 6, both tried to navigate a discussion to bring student talk and sensemaking forward, the pressure to move forward with a lesson plan due to limited planning time meant the discussion about using images to elicit student talk did not materialize.

Figure 3. Visual and Verbal Science Concepts. A sample image of a typical presentation slide showing visual and verbal science concepts.



Occasionally, the propositions that addressed more ambitious equity frames were evaluated and constrained due to limited time and the teacher's prioritization of science content. In the following example, the teachers had previously raised the idea that plants do not exist solely to provide oxygen for humans, as a way to teach students that plants perform cellular respiration in addition to photosynthesis. They wanted to challenge the common misconception that a plant's purpose is to produce oxygen and connected these ideas to indigenous perspectives of the interconnected, non-hierarchical views of nature. In this episode of talk from planning meeting 5, the teachers moved from that proposal into considerations about how they wanted to structure the lesson.

8	Erika	It’s just really hard to think of a phenomenon that's like “what's the purpose of plants?”

9	Hattie	Haha, what do plants do for us? Why do we need plants?
10	Erika	I mean, I'm trying to think of a way to make 'Pea in the Lung' fit.
11	Hattie	We've also used the ecospheres, which is like a really obvious example of the carbon cycle, although the brine shrimp will die
12	Erika	Mine are still good! (3)
13	Hattie	**We could just dive into the content first,** and then circle around to the phenomenon once they know a little bit more.
14	Erika	So then what would we want to do for it?
15	Zach	Well, **I think it's a little bit different for us** because we have them know more about cellulose now and they know about carbohydrates and macromolecules.
16	Hattie	Okay, let's calendar stuff out because I am feeling a sense of urgency because you need to know what you are doing Monday.
17	Erika	I'm okay with just doing matter vs energy. Like that's a good chill thing when kids are stressed out from a move.
18	Hattie	What do we think about not doing an initial model at the beginning, but then doing it further in.
19	Zach	**I think that's fine**.
20	Hattie	**Like a week or a couple of weeks of content** about the respective processes. And then we introduce a thing like a Pea in the Lung, or Ecosphere.

In lines 19 and 20, after considering a new approach to their unit that featured indigenous perspectives, they proposed activities they were more experienced with, which did not connect to the indigenous perspective they originally wanted to include. Hattie suggested that the team focus on content before engaging students with a phenomenon, citing that

students needed more content knowledge before they could engage with phenomenon-based sensemaking. In line 15, Zach attempted to push back on this idea, but Hattie responded by sharing that she feels pressure to get the lesson planned. Erika pointed out that students had recently had to change their schedules, which supported Hattie's proposition to dive into content first. In line 20, Hattie clarified that she's considering using the next 1-2 weeks of classes to focus on content instruction before introducing a sensemaking activity. The conversation then shifted to a 10-minute discussion of the science content they wanted to include in their lecture slides. Eventually, they came back around to a new phenomenon, a cute dachshund who was attempting to lose weight, with the focal question of where the mass the dog lost went. The activities prioritized the science content they discussed instead of ways the teachers wanted to support student sensemaking or ways they could attend to indigenous perspectives in their science classes.

Unfamiliar Practices Lead to Traditional Practices

In chapter 4, I described the goals the teachers worked towards during their planning meetings, including an episode of discussion in which the teachers grappled with embracing heterogeneous sensemaking using a driving question board technique. In that example from planning meeting 6, there was a conflict between the teachers' stated goal of promoting students' agency and choice and their preferred planning practices, which prioritized a single clear path of accessible instruction. They discussed being unsure how to handle diverse student sensemaking, with Zach saying, "it's giving them the illusion of choice," and Hattie responding with "Actual choice is a lot to manage with multiple classes." Similar examples arose across the meetings I observed, during which the teachers considered activities that elicited students' diverse ideas, required them to respond to those ideas, and facilitated whole-class sensemaking discussions. The teachers seemed to view these practices as not playing to their strengths. At the start of the year, in planning meeting 3, I noticed they were unsure how students would

respond to a question about the impact of ultraprocessed foods, and I asked them how they supported students sharing their ideas out loud. Zach responded, “We plan a lot of pair share, and popcorn share-outs, and circle sharing, but I haven’t done any open form discussions.” Across my observations of their classes, I saw each of these formats, which featured students taking turns responding to typically closed-ended questions, but did not involve students grappling with each other's ideas or the teacher supporting the consolidation of the class's ideas. The teachers used student talk to formatively assess students, rather than embracing diverse sensemaking and using students' ideas as a resource or learning opportunity.

With this in mind, I paid attention to moments during planning meetings that might have revealed opportunities for teachers to attend to their goals of student agency, generativity, and sensemaking. In planning meeting 6, when the teachers were considering a lecture on cellular respiration in plants to replace a phenomenon and modeling activity, I engaged the teachers in a discussion about their proposition of a lecture by asking, “What opportunities do they have to figure something out, and make the connections that help them to store what they are understanding? Is there a social implication that is connected to how we treat plants, how we think of plants as providing for us?” If the teachers were going to lecture about plant biology, I wanted to see whether they were considering how students might have space to make sense of the biological processes, or whether they were helping students connect cellular respiration to issues that would be meaningful to students. Erika responded;

> One of the major things that I think is a misconception is that kids do not think that plants do cellular respiration, that plants exist to, like, serve us and give us oxygen. First of all, the oxygen comes from water, not carbon dioxide anyway, but I feel like we could get at it that way, like we could use the shrimp, ecosphere thing. I could see like a, I think we could do like a social thing like, but I really want them to get the body of the plant is used

to do it, and like I don't know. Like, kids really think that plants don't do cellular respiration. That drives me up the wall.

In Erika's response, she took a deficit view of student sensemaking, framing students' process of figuring things out as an opportunity to correct a misconception. She did not offer ideas on how students might connect cellular respiration to a relevant social justice issue they experience. She framed the problem as what she wants the students "to get" and prioritized her preference for correcting misconceptions. The conversation then continued as Hattie and Erika discussed what information they wanted to share with students in the lecture. They misinterpreted my question about providing students with opportunities to make sense of the content, responding with a focus on which scientific concept they wanted to convey to students. I didn't sit with this struggle alongside the teachers and hold us all collectively accountable to our shared goal of foregrounding student sensemaking.

As the teachers planned their unit on photosynthesis and cellular respiration in planning meeting 5, I encouraged them to consider how they could link the science content to relevant or meaningful issues and how they might provide space for students to make those connections. In the following example from planning meeting 6, Hattie considered how students might make interesting connections to her teaching on elodea.

21	Matt	Do you think you have the capacity or desire, or do the students have the desire to make it more meaningful than just like typical elodea? Do you want it to be more than just content-focused? Do you want it to be also like a way of attending to an issue that might be more important or more interesting?
22	Hattie	I think starting with a phenomenon would be good. But like the chunk you

		can do within three class days is just not much. Cause we're going to spend most of that time just getting the content down.
23	Matt	If you had more time, and you thought of a phenomenon, like the algae fuel. How do you think students might relate to the importance of growing algae? Or what phenomenon are you thinking of?
24	Hattie	Probably the algae fuel one, honestly. How does photosynthesis play into it? I'm also just waffling because it's only a week, and we don't have time for all that. **So yeah (8) I don't know. I just need to choose something, though. (94) I think I'm just going to go with the algae biofuels thing**. I just don't have a clear enough idea of how to do that student idea thing.

Hattie struggled with considering how students might think about the phenomenon and make relevant connections. After a minute and a half of silence as she looked over materials and resources, she admitted that she doesn't have a clear idea of how to facilitate a lesson that elicits and builds on student ideas. In this moment of uncertainty, she turned to the parts of teaching she was more familiar with, such as content delivery. Hattie justified this move as being a requirement due to the limited time she had. Making science content relevant to students is a complex skill, one that even expert teachers do not execute effectively every time. Given the limited capacity, due to time and resources, Hattie felt it was necessary to move forward with using lesson materials she already had on hand.

A moment during planning meeting 7 also revealed how this group of teachers was not supported in attending to students' needs using methods that centered on sensemaking. The teachers were discussing how they all had students who seemed very resistant to doing any of the classwork, especially when it came to writing on paper. In response to this, they shared how they modified assignments and met with the student one-on-one to set goals, such as writing just one sentence rather than a full paragraph explanation. They justified this as meeting kids

where they are and teaching to the students' needs, and related it to the work of having a more equitable class. I had noticed a trend earlier that the teachers focused on adjusting the difficulty of science content as the primary way they approached accommodating students. I shared this observation through an email with all three teachers, and Hattie responded, saying, “I feel like this is accurate for me. I am often overwhelmed by all of the things that my lessons could or should contain, but ultimately the content still wins out for me most of the time.” I echoed the ideas of this email exchange back to the whole group during planning meeting 8:

25	Matt	Can I share an observation that I don’t know if it's true, but I’d love to hear if you think I’m off base with this? One of the things I’m hearing, especially when we are thinking about students who are just not doing anything, when those difficulties or dilemmas arise with students, the learning expectation shifts toward minimal science content.
26	Zach	Yeah, definitely
27	Matt	If that's true. What would it look like to shift and meet students at a place that is about their identity, their culture, or what they already know? Like their prior knowledge, their life experiences, ways they could be creative, or things they are interested in. What would that look like?
28	Zach	**Yeah (4) I mean (2) I think it's possible. (6) like (10). I think about Nate. (3)**
29	Erika	I mean, I’m just like, **this project is too fast for me.** I would have started with something smaller at the beginning and done this in the second semester when they know more. It's just too, I don’t know. It's really hard for me to do it this fast. I think with some kids, I’m just going to tell them they have to do, like Nate, you have to just write two words down. Then I

		come back to him every minute and nothing. **They are also learning how to school.**
30	Hattie	I'm feeling a little cynical right now because I feel like if I put up for my whole class like "Green roofs, where should we put them in Adams County? Whose got some ideas?" **I'm just going to get, like, a lot of silence.**

Zach agreed with my observation but struggled to offer ideas for structuring a lesson and student supports that would elicit their ideas or reveal their interests. His response was punctuated by pauses as he considered what that would look like. His thinking was then interrupted by Erika, who rejected the premise I offered and instead pointed to the need for this unit to come later in the school year, after students had been taught more content. While Zach considered how to build on students' prior knowledge or interests, Erika moved past such considerations and restated her main problem and solution to teaching more content. By line 30, Hattie then reflected on how she imagines students might respond to her efforts to elicit their ideas, and how she fears the silence she'd get from students. For Hattie, she was uncertain about how to facilitate or set up a conversation that elicited students' ideas and how to use those ideas as learning resources in the classroom. Without knowing how to do such a practice, she avoided structuring her class in ways that led to those discussions.

Despite having stated goals to promote students' agency, creativity, inquiry, and sensemaking, the teachers struggled to develop lessons that incorporated these practices. They seemed to lack clear examples and resources to envision activities that made space for students' heterogeneous sensemaking, often reverting to their more familiar practice of delivering science content. This again points to the supports that equity-oriented teachers need

to attend to their commitments to make their classrooms more equitable by supporting sensemaking.

Understandings of Sensemaking and Justice

Over the course of this study, how the teachers worked to support student sensemaking and link science to issues of justice revealed their conceptions of sensemaking and justice. As I explored in chapter 4, the ways teachers described their goals contrasted with how they enacted those goals. In this section, I show how the teachers proposed pedagogical moves to support sensemaking or to make links to justice, but then engaged in discussion and reasoning that assumed sensemaking did not include student agency or uncertainty, and that teaching for justice meant providing students with instruction about justice issues.

When explicitly discussing their goal of supporting student sensemaking, the teachers described sensemaking as a process in which individual students build explanations of scientific phenomena, but did not orient themselves to classwide group sensemaking of phenomena. They also talked about how they wanted to do this through supporting student agency and creativity as they grappled with uncertainty. In the initial interview, Zach said, “I value student agency and want to allow for more students to direct where the learning goes.” In the post-study interview, his colleague Hattie questioned how well they were able to attend to agency and sensemaking at the same time, saying, “I wonder how central agency is to sensemaking, like we prioritize a very purposeful sequence of learning that supports students to explain phenomena. But students don’t have much opportunity to choose things.” This balancing of a very purposeful sequence of learning and making space for students to choose how to explore ideas occurred frequently in the teachers' planning meetings.

In the following example from planning meeting 5, the teachers discussed a modeling activity and how they wanted to structure it for students. This surfaced the teachers' ideas about

which features of a model were important and how they wanted to ensure students attended to those features during the lesson. They discussed how they could attend to students' sensemaking and how they returned to a clear instructional sequence that minimized students' uncertainty.

31	Hattie	What are the important things to have in a model? **Symbols?**
32	Zach	**Yeah, to represent abstract ideas,**
33	Erika	We should agree to a key, what the symbols mean.
34	Zach	I always ask them to have a zoom-in bubble to show what's going on that you can't see with the naked eye
35	Erika	I'm assuming if we ask them to zoom in, but what are they going to draw? **When I ask kids to draw atoms or molecules, its real interesting. Like, there are whole books about that, like**…
36	Hattie	Like circles or wiggly lines
37	Zach	But **I think that's important, right? Like it's important to decide how we are going to represent those things** even if we don't know what they look like, and maybe eventually we teach the structure of CO_2 and Oxygen.
38	Erika	But would we want… would we have the bubble? Like if we had a bubble showing like what's leaving? **I want to make sure students are getting the structure** and know how the carbon is coming from respiration.

This episode started with a request and a proposition from Hattie to include symbols of abstract ideas. Instead of identifying the specific content they wanted students to include in this model during a unit on cellular respiration, the teachers started by considering which symbols would help students make sense of their models. Zach extended the idea to include zoom-in

bubbles to help students focus on the model's microscopic features. Both of these ideas are content-agnostic, which gave them space to discuss their teaching at a step removed from the often-prioritized goal of providing clear content instruction. Symbols and zoom-in bubbles, if offered to students as tools they could choose from when making models, worked towards the teachers' goals of supporting students' diverse sensemaking and agency. Erika briefly makes moves in both lines 33 and 35 to define and settle on a set of ideas that will be represented in the model by students. In line 37, however, Zach reinforces his idea of the importance of making space for students to grapple with how they imagine concepts look before the teacher teaches those specific molecular structures. Zach reinforced a responsibility he felt was important that aligned with his goals of promoting agency and supporting students' sensemaking. Erika, in line 38, ended this exchange by reinforcing that she wanted to name specifically what the students would include in their model. The conversation ended after this comment, as the teachers moved to discuss another matter.

In a similar way to how the teachers enacted sensemaking activities to limit agency and student choice, the teachers also focused their teaching of justice on instruction about the links between justice and science, while avoiding using science learning to promote students acting in the service of justice. Hattie noticed and named this tendency during her post-interview when I asked her about how, during this study, she worked toward justice. She said, "Justice, at a minimum, is creating knowledge *of* diverse perspectives. But going beyond that, justice is giving students agency and empowering them." Hattie then reflected that as a team, they were only able to work on the empowerment piece a little bit during their project-based unit on climate change. In chapter 6, I explore how the teachers approached their goals differently during their climate change unit; however, these orientations were not evident during their initial planning meeting at the start of this unit.

The teachers grappled with how they wanted to teach about the justice issues associated with climate change, and how they wanted to position students with agency to act for

justice during planning meeting 7 before their climate change unit in late November. The lesson they were building on from the year before had students read a speech by an indigenous activist at a United Nations Climate conference and then write a problem statement that pointed to how climate change is impacting communities, caused by the release of carbon dioxide into the atmosphere. This year, the team proposed ways to modify the assignment to better attend to justice by making the speech more accessible and helping students identify how to respond to the calls to action.

39	Erika	I think this reading could go into Indigenous Heritage Month. If we are talking about perspective, It's a very different perspective than the Western science perspective. This is thinking about community. **We should show the picture of humans in the circle versus the triangle with man on top, which this speech is showing. and why, and how can it help us**… (2)I'm looking at this speech, and 'it's important how we respect nature' and then how we challenge Western nations to do what they need to do. Then you could use that to go back to the graph and relate it to how the US has put all this carbon dioxide in the atmosphere and ruined it for other people. I would chunkify it more and connect each part of speech to each part of either indigenous perspectives or Western science perspectives.
40	Matt	If you just focus on the problem statement, the strict scientific cause of the problem is just CO_2 from humans. Like the NGSS wants to focus on "climate change is happening because we're adding too much CO_2' but if we go beyond science=
41	Erika	=It's Capitalism, greed,
42	Matt	=Western perspectives of resource extraction, not being in relationship

		with the world.
43	Zach	The IPCC report says climate change is due to colonization.
44	Hattie	**But the purpose of reading the text is to figure out the problem of climate change, to fill out their problem statements.** We need students to say that it's caused by carbon dioxide in the atmosphere, which was released primarily by wealthy countries.
45	Zach	Maybe spend some time asking them what impacts are personal to you, and then go into the packet with that framing? **The problem statement could be more open than that, like how they are going to take action on it.**
46	Erika	**But that's asking a lot for this activity.** We should show them the speech and have them fill in their climate change statements with, like, they can choose from a list of who or what is causing the carbon.

At the start, Erika noticed an opportunity to connect the speech to indigenous perspectives and wanted to make those connections more explicit than they had been when they taught this lesson the previous year. She had stated goals of attending to a wider range of perspectives in her science teaching and wanted to reorganize this activity to emphasize those connections. In line 44, Hattie pushed back to ensure that the new activity structure still functioned to help students develop a problem statement that linked the activist's speech to the explanation of carbon and climate change. Zach's response indicated how he wanted students to use the problem statement to connect their personal experiences with the activist's story and use that information to guide their upcoming projects. Erika, however, dismissed this suggestion and reiterated their goal of providing students with accessible instruction to explicitly teach about justice and science.

These examples show that the teachers held complex concepts of sensemaking and justice but often used more limited ones as they enacted and solidified lesson plans. In the first example, the teachers took a step back from focusing on the specific content they wanted students to include in their models and discussed content-agnostic moves that would support students in making sense of the model in more heterogeneous ways. However, they then returned to ensuring they had explicit instruction on the science concepts students should understand, demonstrating the conflict they experienced between their goal of providing accessible instruction and their goal of supporting students' agency and creative sensemaking. In the second example, the teachers discussed how to teach about diverse perspectives on science, capitalism, and who is responsible for climate change, making complex pedagogical decisions about how to support student learning. Zach offered to use this as an opportunity to empower students to connect the global context of climate change to local issues they could act on as agents of change in their community. And yet, they settled on attending to justice by teaching about diverse perspectives without attending to how students might act with or for justice.

While the examples in the chapter came from episodes of teachers planning across multiple units of instruction, one unit in particular helped the teachers orient to aspects of their equity goals that they had struggled to attend to in other units. In the next chapter, I explore how the teachers' project-based unit on climate change in their local contexts made space for them to promote students' agency and creativity while attending to meaningful local issues that students cared about.

Chapter 6: Shifts in Teaching Practice for Agency and Justice

Unlike the prior units of instruction I observed, the teachers at Echo High School designed and enacted a project-based climate change unit that required them to center student agency as a driver of learning and to teach with the explicit goal of promoting justice rather than merely teaching about it. This unit, along with the planning work around it, supported teachers in developing more integrated and holistic conceptions of equity across their three professional goals. In this chapter, I provide evidence to show how this played out as I answer my third research question: How did ambitious project-based instructional units help teachers address equity goals? I start by describing the project-based climate change unit and how it differed from other units, and how the teachers modified it as a result of their work in this research project and their three identified goals. I then present excerpts from a planning meeting and examples of students' work from classroom observations to show how the teachers grappled with learning grounded in student agency and empowered their students to use science as a tool to promote justice. I end with an analysis of how the teachers' views of equity and their collective efficacy in teaching for equity and justice shifted over the course of this study.

Project-based Climate Change Unit

This unit on climate change came at the end of the first semester in the freshman biology course. The teachers sequenced this unit to build on prior topics of photosynthesis, cellular respiration, and the carbon cycle. This unit addressed science standards related to the role of carbon in the atmosphere, human impacts on the environment, and engineering processes (NGSS Lead States, 2013). While the teachers usually built their lessons on the OpenSciEd (2022) curriculum adopted by the district the previous year, this climate change unit was one they initially designed four years earlier and had been iterating on each year since. The unit's basic outline had students develop problem statements, based on textual resources, that describe what climate change is, its root causes, and how it could be solved. Then, after

providing additional instruction on sources of carbon dioxide and the greenhouse effect, students chose a single climate action to research and build an understanding of. The unit culminated in student presentations about their chosen solution and how it could be implemented in their local county.

This unit was cited by the teachers during my pre-study interviews six months earlier as an example of how they addressed various goals they were working on and how they viewed equity in their classes. The teachers held this unit in high regard as they felt it was both an important topic and an exemplar of how they worked towards their ambitious equity goals. “It’s probably my favorite unit,” Zach said in his exit interview, “and by necessity, because it is a project, it has those components of equity and students make sense of applying climate change.” Additionally, the teachers frequently referenced this unit during the post-study interviews as they reflected on their goals. As I quoted in Chapter 5, Hattie described how she prioritized a clear sequence of lessons that support sensemaking, but that meant students didn’t have opportunities to make choices. Hattie continued saying, “In the climate change unit, they did, but that was sort of different.” In a similar statement about their justice goals, Hattie said, “Justice is giving students agency and empowering them, which only worked in our climate change project.”

This unit differed from the teacher's other units of instruction in important ways. Whereas other units focused on disciplinary core ideas and structured student activities around developing explanations of phenomena in line with those disciplinary core ideas, the climate change unit was structured as a project in which students applied engineering and design methods to research and evaluate a climate change solution in their local region. In prior units, students' agency and choice were limited, only seen in small variations in how explanatory models were laid out. In the climate change unit, student agency was foregrounded as they had to both select a climate change solution to research and decide how that solution might best be enacted in their community. During planning meeting 8, Hattie named this approach as different

for their students, saying, “It’s a really big jump… giving them not a lot of structure …. They are not positive that the things they are pulling up are actually answering the question. Because they are used to finding the answer in the text.” While students were familiar with finding answers in teacher-provided texts, this unit asked them to apply solutions locally in ways that were not explained in any single source. Students had to make choices and support their ideas with various forms of evidence, combining sources and making creative inferences between pieces of evidence. Further, the local applications of the climate solutions were unique to this unit. Other units often featured discrete phenomena that students engaged with as they built an understanding of science concepts, and the goals were to develop a general understanding of these concepts. The climate change unit explicitly asked students to use generalized solutions to climate change and explain how they might be applied locally, applying general solutions to local context in creative ways, thus positioning students with agency to take action in their communities.

Additional unique features of the climate change unit can be seen in how the teachers modified it over multiple iterations as they worked toward their equity and justice goals. This unit downplayed the content-focused approach that dominated most other units. When I asked about this unit during the post-interviews, Zach said, “Content wasn’t the core objective. The project was more about the connections between justice, agency, and sensemaking. The students come in with a lot of climate change knowledge.” He described how he and his colleagues had noticed that students were familiar with the basics of climate change, and that they planned this unit to come after their unit on carbon cycling, so they didn’t have to spend as much time telling students all the science ideas, a change they made after previous years' observations. Similarly, Hattie described how, in previous years, they spent more time having students create models that explained how greenhouse gases cause climate change. Instead, this year, they gave students more time to research their climate solutions. Hattie justified this change during her post-interview, saying, “There was a deeper reason to learn because they

had to figure out the local applications, not just learn it for the test. So we had more student engagement." In addition to addressing what students already knew, the teachers modified this unit for this year to provide more student support in less-known areas by recruiting teachers outside of science. The biology teachers collaborated with math and social studies teachers, turning this unit into an interdisciplinary project in which students could conduct deeper data dives in their math class and build an understanding of current social justice issues in their social studies class.

As the teachers continued to iterate on this unit, the unique features that emerged also presented opportunities and challenges for them to navigate. This year, the teachers scheduled the unit to give students more time to work on their climate solutions research rather than to develop a model of the greenhouse effect. This shift created space for the teachers to work towards their equity goals around student sensemaking and linking science to issues of justice. This year, the students grappled with guiding their own research for longer periods, which posed a problem of practice for the teachers, who needed to figure out how to support their students through their productive uncertainty (Manz, 2018). In the following sections, I explore how they grappled with teaching with student agency and for justice, and what lessons the teachers learned from this experience.

Teaching With Foregrounded Agency

The teachers grappled with how to support students' sensemaking differently during their climate change unit, as students were given agency to guide their own investigations. The teacher's typical routines of highly structured learning sequences were not useful in this unit because each of the student groups during this project was working at different paces to understand different climate solutions of their choosing. During planning meeting 8, the teachers quickly launched into sharing their noticings about how students were progressing in the unit and started discussing their problems of practice. This episode of talk began immediately at the

start of the meeting and shows how the teachers initially tried to address their dilemma by returning to structuring the learning.

1	Matt	How's the climate change unit going?
2	Hattie	Pretty well. The project work has been a little… uneven. (2) haha
3	Zach	((*sighing*)) I would love to hear from you all. Because I need to have a little more structure to my projects and stuff tomorrow and Thursday. And **I need to figure out what I need to do to make worktime more structured?** I struggle with checkpoints. I give them a finish line, but I feel like the checkpoints are so … (2)
4	Erika	There should be more formatives
5	Hattie	**They need to be more measurable.**
6	Zach	There needs to be *more*, but there aren't that many. Cause they're spread out.

In line 3, Zach, hearing that Hattie was having a similar problem of students not making progress on the project, explicitly requested to hear from his colleagues about how to better structure students' work and the daily lessons. He proposed checkpoints to monitor and provide feedback to students, an idea Hattie and Erika agreed with, adding that more measurable goals would be helpful for providing feedback. In this project-based unit, the teachers planned multiple days for students to work in groups to research and describe a local climate change solution. The teachers provided students with a rubric for the final products and occasional checkpoints to guide students' progress. The problem of practice that Zach surfaced demonstrated that both the students and the teachers were struggling to organize their work in ways that helped them move forward, and that the teachers were struggling to provide structured student support. As the students researched climate solutions of their own choosing, the teachers could not provide

a clear, direct path of instruction that was the same for each student group, though they wanted to provide more structured checkpoints to guide students' progress.

To help the teachers explore the conflict between their goals of student agency and clear instruction, I highlighted a tension between planning specific steps for students to follow and providing space for students to take a wider range of paths to complete their own projects.

7	Matt	I think that it is sort of tricky, because when you, as the leader of the class, **you can say 'this has to get done by this point', but when you are giving these projects to students, there is enough diversity in what they are working on that there isn't a clear path forward, right?** So one group might be able to do slides 1-2-3 by this day, like following the checkpoints, but another group might need more time to just explain their solution. So like, what checkpoints might be general enough to be adapted to the diversity in the room, and be meaningful to each group's project?
8	Zach	I wonder if the goal could be for each day to **do one part of the rubric.** Like day 1, you have to have the beginning section done and then its not divided up with each person doing separate parts. I think I'm going to do that tomorrow. Like 'don't even do Meets and Exceeds yet, just make sure you have Beginning and Approaching done today.'
9	Hattie	yeah, because it builds on itself
10	Zach	because I think the hard part of dividing it up, while I like that they have individual jobs, but a person doing a level 4 thing really relies on the people at levels 1 and 2.

Zach and Hattie initially did not take up my suggestion to explore in depth how specific rubric-based checkpoints might limit students' research across their diverse projects. By centering checkpoints, they prioritized providing a single, linear path of progress for students to follow. It wasn't until later in the meeting that we were able to redefine the problem away from giving discrete end goals and checkpoints and instead discuss how the teachers might hold students accountable for progress without limiting the different ways progress was made.

The teachers discussed ways to support learning while preserving the students' agency and creative decisions. In this unit, student groups chose which climate solution they wanted to research. They were also asked to make creative choices, based on a range of information, to suggest how that climate solution could be implemented in their local county. Students needed to apply general principles of climate change solutions to specific local contexts. This led to many instances in which students had to grapple with uncertainty about how to realistically take climate action, without a clear set of instructions to guide them. The purpose of this project was to make space for students to sit with productive uncertainty as they made progress (Manz, 2018). After discussing variations on providing guidelines or checkpoints, the team discussed ways they could support students as they circulated around the room to each group. I asked a question to connect the teachers' issue with student progress to how they were supporting each group, one-on-one.

11	Matt	Is there something that you can do to support some of the issues that you are seeing, like helping students make progress so it's not all done at the very end?
12	Hattie	Ideally, I wanted to **use next Monday and Tuesday to do peer edits** and revisions, but they would have to have a finished product by then, which I actually doubt will be the case.
13	Matt	Could you take like 15 minutes at the end of each class period and do

		like a mini-peer edit? And do that each day? As a way of helping them check in with each other, check each other's work, understand what the other people are working on, start to see connections between each other, rather than doing it all as one big peer edit at the end?
14	Hattie	We could try that.
15	Erika	It's a good idea
16	Hattie	Like, share with another group what you found
17	Zach	Yeah, that's what we talked about for the last day, too. Or we could just do like the lines, share between two people
18	Hattie	Yeah, like what did you research today? Explain it. Like have one parter share and then the other one, talk about how you could make it stronger and clearer
19	Zach	Or just ask questions about it, go deeper
20	Hattie	Restate, ask questions. **That would also work as our check-ins to see which group is making progress**, and then we can go to them first the next day and make sure they are moving forward.
21	Zach	**Instead of like the rubric, we can just help them see each other's work**, and then we'll know who's getting what done.

Hattie shared that she planned to use time at the end of the project for students to provide each other with feedback, but that activity relied on students having already made sufficient progress. I proposed doing the revisions in smaller steps each day, using students' peer-to-peer feedback to act as an accountability tool and as a way to support collective sensemaking among students. Zach and Hattie iterated and clarified how they would organize that lesson. And, in lines 20 and 21, they explicitly called back to their problem of practice related to students' progress and preserving students' agency. These daily peer feedback

sessions became a critical strategy for the teachers to support students during the project. In a post-study interview, Erika reflected on this strategy. “The peer feedback helped a lot… We were able to use the district's accountable talk moves. Talk is how you make sense of things. We didn’t have to tell students. They just talked it out in their groups.” Using this strategy, the teachers were able to reduce students' dependence on them for answers, and students turned instead to each other for support in their learning.

While the peer-feedback strategy helped students make broad progress, the teacher also noticed that students struggled to apply the climate solutions to local contexts. This also emerged as a unique feature of this project-based unit. In other units, students could rely on gathering information from texts, figures, or their own experiments to answer the teacher's questions. In this unit, the teachers asked students to generate novel applications of climate solutions, specifying how those solutions would be funded and rolled out. During planning meeting 8, the teachers noticed how students were struggling to come up with specific solutions and designs. They wanted to address students' ideas and the questions they were hearing from students.

22	Hattie	I’m getting so many questions around ‘What is Adams County?’ ‘Where is Adams County?” like, okay, here’s a map of Adams County. That’s what I had to lead a lot of groups through, **like you have to choose the scope of your project.** Like this is in Adams County. It could be one city in Adams County, it could be our school, it could be the whole county. How are you going to decide this?’ that was like a thing.
23	Erika	There were groups that I found halfway through that were like, ‘I don’t know what I’m doing.’ Despite having directions in twelve different places. Of like, ‘what’s your solution?, uh, what?’ so that’s how that goes.
24	Zach	It’s hard because, especially with the location of the project pieces of it.

		It's so context-dependent that it's sort of the only way to do it, I've found. Because each group has to look at a different map to find how to answer their question, basically.
25	Hattie	In the freedom to choose, it makes it very difficult to support, when you aren't just individually talking to each group, so it turns into a bit of whack-a-mole. Where I have to go to the table and be like, 'remind me what you are doing again, where are you?' and then problem solve.
26	Matt	I wonder if there's much crosstalk at the table of students trying to problem solve with them at their table, before they call you over?
27	Hattie	It varies greatly.
28	Zach	I find more independent groups are doing that, and they don't need my support. Half the support that I am giving is getting them talking about the question
29	Erika	**What do you think is the barrier for them?** Is it content? Is it social? Not knowing the process?
30	Hattie	I think a bit of all of those. I think this is a jump, right?
31	Erika	It's a BIG jump
32	Hattie	**It's a really big jump, which I, we've done a lot of practice finding meaning from text, like, using it to be able to answer a question. But giving them not a lot of structure and being like, answer this question. They are not positive that the things they are pulling up are actually answering the question. Because they are used to finding the answer from the text**
33	Zach	**This is generative**.
34	Hattie	I think we could give more practice with a research-type project that

		doesn’t have twenty parts in the year before this, like how you could scaffold in part of the research.
35	Zach	Like, individual, with just one issue
36	Erika	Yeah, like in the photosynthesis unit, they could research something they have to use the database for.

Hattie started her observations with a deficit lens, describing how students seem not to know information about their local county and the context in which they are being asked to apply the climate solutions. In line 24, Zach shared that context is very important to the project and that he has to use different materials with each group. Hattie related this to a fundamental difficulty in providing students with choice, resulting in the teacher having to problem-solve and provide a different set of instructions to each student group. Erika, in line 29, asked the group to consider more deeply the barrier students were experiencing, which helped her colleagues identify how this type of work is “a jump” compared to how they typically teach. At this moment, the teachers made a significant shift away from their initial deficit framing of students' lack of knowledge and instead considered their typical teaching approaches. Hattie noticed that they do a lot of learning in which students have to pull information directly from the text, and yet this task asked students to make broader inferences or conjectures about how to apply climate solutions in local contexts. She said that students weren’t sure whether the results they found in their internet searches were relevant to the issues they were working on. Zach pointed out that this is an example of generative learning, which he has said is one of his goals. Hattie offered that in the future they should shift their practice to take on smaller projects, building up to a larger project like this climate change unit, and giving students more practice engaging in creative problem-solving and open research.

Later in this same meeting, the issue came up again as the team discussed ways they could support students in making creative choices in how to apply their climate change

solutions. While the previous discussion offered some ideas for supporting students, the teachers continued to grapple with how to design instruction that was clear and accessible while also promoting students' agency and choice.

37	Hattie	I think also we touched on this a little bit, too, but like those questions that are sort of like, require some creativity, and deal with the multiple directions, like “where do I put this in Adams County?”
38	Zach	Yes, what are we doing for that?
39	Hattie	**How do you direct a kid on what to do who has no idea what to do? It's very specific for their solution, right? So you have to problem-solve with them individually. I don’t know how to do that.** Like, I realize this every year, and I’m like, it's on the rubric, but how do I actually structure instruction for a kid to do that part, especially if it's like a kid that is not independent in their work? Like, if the idea is to put on green roofs and they have to choose somewhere in Adams County, like, how do you direct them to where to choose? Like, what are the steps?
41	Zach	I always just sit down with them and look at the maps, they can be more creative when they have information to build from.
42	Hattie	yeah, like pull up a chair and look at a map of Adams County and look at where stuff is, **But being local, I know they know the area they live in**.
43	Erika	I like that, **that’s so important for them.** Not just to know that climate change is happening, but to be able to step up and point to the map and be like **‘right here, this is what we need to be doing**’.

In returning to the topic of the ways they are supporting students to make creative decisions about climate solution applications, Hattie initially, in line 39, centered the problem on

how to provide a clear set of steps for students. This framing of the problem prioritized the teacher's goal of clear and accessible instruction. However, Zach suggested activities to support creative thinking. Hattie built on these ideas to explore how looking at individual maps and data sets with each group might help students to have information to base their creative solutions on. Hattie, by line 42, reasoned that students could use their prior knowledge of the neighborhoods they live in to see places represented on the maps she provided. The planning meeting shifted directions after these comments to findings maps and graphs they could provide for students, as well as how they could help the math teachers use the same graphs in their classes. The teachers designed activities that supported students in applying their chosen solution by providing them with local and relevant datasets, centering students' sense-making process rather than teachers' content delivery.

Erika's comment in line 43 also pointed to how the teachers were thinking about positioning students with agency beyond their own classes. While this planning meeting focused on how they were supporting students' learning while preserving their agency to choose different topics to research, this work also helped the teachers approach their goal of justice by empowering students to act on climate justice issues.

Teaching With and For Justice

Over the course of their project-based climate change unit, the teacher worked toward their goal of linking science to issues of justice in ways they had not previously. Before this unit, the teachers taught about justice issues and provided instruction that showed how science was related to justice. In reference back to the definition of social justice from the Benjamin Banneker Association (BBA, 2017), this left out the work of teaching with and for justice. However, in this unit, the teachers were able to structure their lessons to enact justice with equitable interactions in the classroom and how they positioned students to use their knowledge to work for justice beyond the classroom.

The teachers' work toward their goal of supporting sensemaking overlapped with their work toward justice as they attended to students' agency. Teaching *with* justice focuses on classroom interactions, ensuring equity in the relationships between students and the teacher, such as providing students with agency to be authors of ideas in the classroom. The teachers worked toward this, as I described above, through their efforts to provide students with agency to choose topics to research and through strategies that positioned students to learn from each other during peer-feedback routines. I observed this during a classroom observation in Zach's class on November 17th. During the students' work time while researching their solutions, Zach paused the research to do a class circle discussion. He started by asking students to share the qualities of a good audience member during presentations. After hearing from a few volunteer students, he asked all the groups of students to take turns sharing what they thought their audience might find interesting about the climate solutions they had researched so far. As the groups shared, Zach responded with encouragement, highlighting ideas students shared that other groups could build on and naming norms for supporting each other during the upcoming presentations. In this activity, Zach created a space for students to share their ideas with their classmates. This allowed Zach to monitor and assess students' progress while also positioning students as the authors of ideas and concepts that other students could learn from. Zach centered students' ideas and work as valuable learning resources, allowing students to be the authors of their ideas and disrupting a teacher-centered view of schooling.

The teachers attended to students' local funds of knowledge and creativity during this unit as a way of teaching *for* justice. According to the BBAs' work (2017), teaching for justice means using content-based learning to challenge systems of injustice and empower students to act beyond the classroom. In earlier iterations of the unit, students researched and presented on climate solutions in general; however, the teachers adjusted the unit to have students explore how to implement those solutions locally. This shifted the unit from a focus on learning about climate solutions to students using their local knowledge and their growing knowledge of climate

solutions to generate possible actions their local community could take to address climate change.

During this study, the teachers continued to learn how to support students to use science for justice. The teachers sought ways to empower students to act and challenge systems of injustice related to climate change. By focusing on local applications of climate solutions, the teachers were able to empower students to draw on their funds of knowledge of the local area, as well as provide relevant context that enabled them to take action in their communities. On November 17th, in one of Hattie's classes, I observed that a student group was gathering information on how rain gardens could reduce flooding risks and sewage overflows during heavy rain. They were able to find information about the average cost across the United States to redesign a lawn into a rain garden, and information about the general way a rain garden worked, but struggled to find information about what types of plants should be used in Adams County or how many gardens would need to be converted to deal with local precipitation rates. This information was not explicitly stated in a textbook that Hattie could give to the students. To solve this issue, the student group brought in photos they took on their phones from rooftop gardens and bioswales in their neighborhoods and used reverse image searches to identify the plants. Hattie then provided the students with data on annual precipitation in their region and how often the surface drainage infrastructure was overwhelmed during heavy rains. From this information, the students decided they would need to test rain gardens on five houses along the street where they lived to determine local costs and the effectiveness of preventing excessive runoff.

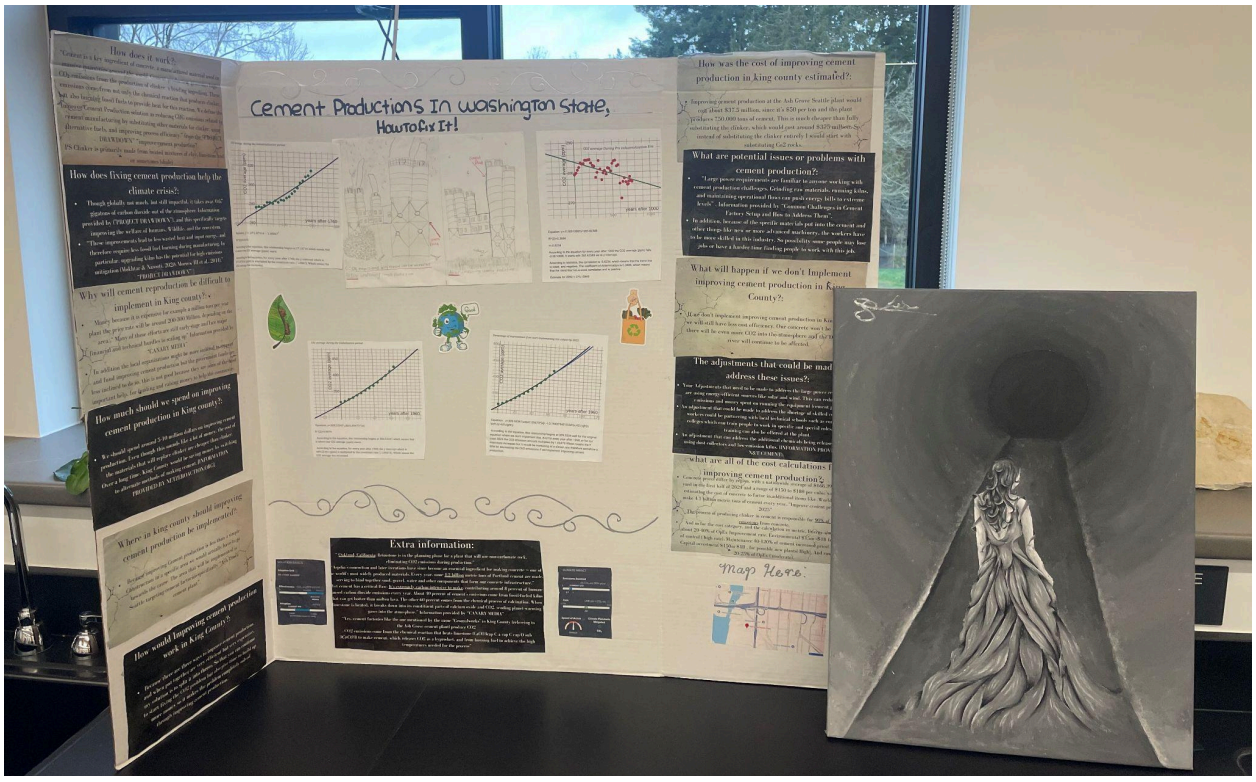
The students presented their proposal for this future study to the whole class at the end of the unit. Hattie also asked them what type of plants the students would put in the rain gardens, to which the students replied that they would remove the grass and replace it with salmonberries and Douglas firs that they knew were native to the region and had seen in other people’s yards, utilizing their knowledge of the local spaces.

Another change the teachers made to this climate change unit was to explicitly request that students engage creatively in developing and presenting their local climate solutions. By leaning into students' creativity, the teachers hoped to engage aspects of students' skills and knowledge that are often not emphasized in science, while also asking students to explore topics they cared about. The teachers observed early in the unit that the students were struggling with taking creative leaps in how they were applying climate solutions to the local region. In response, the teachers included explicit instructions to invite students to communicate their ideas creatively. They encouraged students to add artistic representations to their presentations and to share in diverse ways. In a set of instructions before students' final presentations, they said, “Art is sometimes the most effective way to persuade people’s hearts and minds, in a deeper way than numerical and written information can. How did you use art to persuade our community to support your proposal?” By explicitly requesting that students attempt to communicate their ideas creatively, the teachers made space for students' heterogeneous thinking and communication preferences, providing them with agency in their schoolwork and a request to focus on the issues they cared about.

The teachers made space for students to make sense of essential science topics, while linking local context, issues of justice, and care in tightly integrated ways. In one case, a student group found data on the Ash Grove Cement Company that showed significant carbon dioxide emissions into the atmosphere in the region. During this group's presentation, they shared stories about how they could smell and taste the pollution from the nearby factory and linked this to the abundance of particulate matter in the atmosphere, which impacted the high-poverty neighborhoods surrounding the concrete factory. One student used her time in her art class, beyond the three courses supporting this learning project, to express her ideas in a painting (See Figure 4). She created a painting depicting a woman in a dress standing inside the belly of the concrete factory, juxtaposing the brutality of concrete manufacturing with the flowing natural

qualities of the woman and her dress. The student wanted to use this powerful image as part of an organized protest against the local cement company.

Figure 4. Student Group Presentation and Painting to Protest Ash Grove.



The teachers' work of designing their project-based climate change unit was informed by each of their three goals. Significantly, the teachers were able to attend to student sensemaking and linking science to justice by supporting students' agency, creativity, and learning within the context of local justice issues. During the planning meeting in the middle of this unit, the teachers recognized the ways their students were struggling to make creative leaps and take academic risks that were less familiar to them. Through their collaborative discussions, they were able to propose classroom activities, such as peer feedback routines, that supported students' agency without foreclosing on the creative and diverse ways students were conducting research and presenting their findings. Instead, the teachers leaned into students' creativity and

heterogeneous sensemaking to overcome the detours of other units, leading them to prioritize access and content.

Shifts in teachers' discourse about their goals

In addition to the shift in teaching practices between this climate change unit and their prior units and prior iterations of the climate change unit, the teachers shifted in how they spoke about equity and how they viewed their ability to teach for justice. This shift could be seen in several ways when comparing their pre-interviews at the start of the study in May to their post-interviews in the following January. In the pre-study interviews, they discussed their goals in terms of what they wanted to give students, while in the post-interviews, they discussed what information students could provide to support the class's collective learning. In her pre-interview, Erika discussed her goal of access by sharing how she wanted to “give my students more notebook strategies, and language supports like teach them prefixes and suffixes.” In her post-interview reflection, Erika said, “It's important to know where kids are now and adapt instruction to help them share those ideas.” The teachers shared that they felt more confident eliciting and responding to students' ideas to move the class toward their learning objectives and justice connections.

Another way the teachers' discourse of their practice shifted over this study was related to how they viewed the changes that resulted from their goal pursuit, the telos of their learning. In the pre-interviews, the teachers discussed their goals for what they wanted to add to their practice. Hattie shared how she wanted to “add more social justice connections to my lessons and give more context for the science content.” At the end of this study, Hattie reflected on her equity goals to show how each goal gets attention differently in different units. She said, “The goals always shift in what I can do each unit, so I could focus more on multilingual supports in one unit, but then in the climate change unit, it was all justice and choice.” Hattie's comments shifted to show how she was thinking about her work. She moved from thinking about adding

discrete strategies to a more integrated view of balancing objectives and different ways to emphasize each goal across the units.

Finally, the teachers shifted in how they viewed the role of uncertainty in students' learning. At the start of the study, the teachers stated that they wanted to make their instruction clearer to give students better access to science content and to use more highly structured sensemaking routines to ensure students made sense of the science phenomenon they presented. Zach shared in his pre-study interview, “I want to have clarity in my routines in order to have each student get what they need. I want to make it easy for students to follow.” By the post-study interview, Zach reflected differently, saying, “I want instruction to be clear, but also I recognize that some content needs to be unclear at first and that we are going to be messy with it for a while. And that’s okay.” The teachers' shift toward leaning into and spending time with the unknown demonstrated that they were building greater facility in allowing students to have more authority in the sensemaking process and that they wanted to empower students as active participants in science and sensemaking.

Across this chapter, I have shown how the teachers shifted their practice, particularly during their project-based climate change unit. Due to the structure and project requirements that the teachers iteratively designed into the unit, they were able to attend to student agency and decision-making as a key part of sensemaking in their class activities. The teachers used a peer-feedback routine with students to move away from a linear, teacher-guided process of student progress during the unit and instead used student-to-student discussion to provide accountability and inspiration across student groups. The teachers developed explicit local data resources that students could make sense of to build on students' local funds of knowledge while focusing on local contexts that students cared about. The teachers shifted how they taught about justice, instead supporting students' learning with justice concepts and empowering them to take action for justice. These shifts in teachers' practice were mirrored in the teachers'

discourse about their equity and justice goals. The teachers moved to discuss equity in more integrated ways that built on students' knowledge and made space for productive uncertainty.

Chapter 7: Discussion

The purpose of this study was to examine how a group of science teachers navigated their collaborative planning while learning to implement their equity-oriented goals. My analyses were informed by situative views of learning and teachers' evolving attunement to issues of equity through episodes of pedagogical judgment. Across this study, I identified the goals teachers held and how they oriented their work to achieve them. I explored how some goals were prioritized over others and how the teachers navigated conflicts that emerged between their goals. I also provided a case study of an instructional unit that helped the teachers better center students' sensemaking, agency, and relevant links between science and justice issues. The findings in this study help me to answer my three research questions:

Research Question 1: How do teachers wrestle with enacting their stated equity-oriented goals?

Research Question 2: How do teachers collaboratively navigate tensions among their goals?

Research Question 3: How do ambitious project-based instructional units help teachers address equity goals?

The first two research questions established a foundation for the teachers' practice, goals, and patterns of interaction during their planning meetings, which then provided a contrasting case against how the teachers operated during their project-based unit on climate change. Chapters 4 and 5 addressed these two questions. In Chapter 4, I laid out the goals the teachers held for making their practices more equitable. The teachers said they wanted to provide clear and accessible instruction on science content, support students' sensemaking that allows them to have agency in their learning, and link the content of their science classes to relevant issues of justice in students' lives and in broader society. These goals were not always equally prioritized in their lesson planning and classroom enactments. Due to different aims of their goals, the teachers experienced conflict among their multiple goal pursuits and often prioritized access. Such a difference opens up an important space for inquiry. If the teachers'

day-to-day work of planning instruction conflicts with the goals and directions they would like to improve, how do they navigate those conflicts and tensions? For educational researchers or others who want to support teachers' learning, understanding how teachers navigate differences in their goals and the equity frames they use to attend to instruction is an important process I explore in the next chapter.

In Chapter 5, I found that throughout their planning, the teachers prioritized their first goal: providing students with clear and accessible science instruction. In many instances, the teachers would begin planning with proposals to attend to student sensemaking or to feature important links between science and justice. However, during their planning discussions, the teachers settled on activities that minimized students' uncertainty, resulting in fewer opportunities for sensemaking. In place of these opportunities, the teachers oriented their lessons to focus on the central information they would directly tell students and on instructions that would most clearly help students repeat the canonical science explanation of the phenomenon. In other instances, the teachers proposed activities and teaching moves they were less familiar with but that aligned with their goals. As the group discussed how to enact those lessons, they grappled with aspects they were not familiar with and either modified the activities to rely on a familiar teaching move or abandoned the approach altogether. While the teachers grappled with their equity- and justice-oriented goals, they often reduced their scope to focus on practices with which they were already familiar, pointing to a need for greater support to engage with the complexities of equity-oriented teaching.

In Chapter 6, I provided evidence to help me answer my third research question about how the teachers shifted their practice during a project-based climate change unit and thus navigated conflicts among their goals. In prior units, the teachers generally struggled to attend to their goals of supporting student sensemaking and linking social justice to science. However, in their project-based climate change unit, the teachers grappled with the conflict among their equity goals in different ways. By investigating a problem of practice, the teachers and I

developed a clearer understanding of the teachers' learning goals, which included supporting students in making choices as part of their sensemaking. The teachers reinforced their commitment to foregrounding the justice issues tied to the science of climate change. And finally, the teachers shifted in how they viewed agency, sensemaking, access to learning, and their equity goals.

In this discussion, I explore what factors contributed to the teachers' differences in orientation and action. I discuss how the teachers developed three goals, with each goal informed by distinct equity and science education frames, serving different purposes and outcomes, thereby contributing to the conflict among them. I argue that the teachers were able to navigate complex conflicts among their goals by attending to the context of their students, their pedagogy, and the unit's content. The teachers made space to more fully explore and understand a core dilemma they were all experiencing. They then built lessons that preserved students' agency in sensemaking. Additionally, they embraced social justice science issues central to their approach to teaching climate change and positioned students as actors to bring about justice-focused change in their local communities. I then explore the implications for future research on equity in science teaching and how researchers and teacher educators might use the findings from this study to further our collective efforts to make science education more equitable and just.

Goal Conflict From Diverse Frames of Equity and Science Education

The findings of this study show that the teachers developed three goals they felt would help them work toward more equitable classrooms: providing access to science content, supporting sensemaking, and linking science to issues of justice. In this section, I discuss how those goals align with various equity frames that have been taken up across educational spaces over the past decades. I argue that by drawing on a range of equity frames that serve different aims, the teachers implicitly selected goals that conflicted, requiring them to navigate complex

spaces to find resolution. This study suggests that researchers and those supporting educators should pay attention to the implicit frames that inform teachers' goals in order to understand a possible cause of goal conflict.

During this study, the teachers developed a set of goal statements related to their desires to attend to equity and justice as they learned to improve their teaching. These goals were drawn from their day-to-day experiences with their students, as they identified areas of their own teaching practices they wanted to improve. Additionally, their goals reflected the discourses and initiatives they had been exposed to throughout their professional development. Some of these influences came from district communications, such as a multi-year district-wide initiative to improve student reading scores by focusing on engaged reading strategies and accountable talk moves. Other influences came from the teachers' communities of educators they participated in, such as online communities, their schools, unions, or other organizations. This is all to say that many discourses influence how teachers set goals (Betancourt, 2024).

As I described in Chapter 4, the teachers' goals aligned with the five frames from the Equity in K-12 STEM Education report (NASEM, 2025) and the three approaches to equity in science education described by Lee and Grapin (2025). It is well known that the frames of equity and different goals of science education work at cross-purposes (Huguet et al., 2021; Turner & Spain, 2020). As a part of their access goal, the teacher wanted to provide language supports to their students, but tended to emphasize science content instruction over language instruction. By setting this goal, the teachers continued to use a ‘gap-gazing’ view of measurable student achievement (Garcia & Guerra, 2004; Valencia, 2012), but also named their own practices through a deficit lens as targets for their improvement efforts. The teachers held high academic expectations for their students, focusing on content in order to prepare them for future science coursework (Ladson-Billings, 2021; Short & Hirsh, 2022). They worked to establish welcoming classrooms to provide students with access to science environments

(McGee, 2020), but ultimately prioritized science knowledge and focused on the imperative to address students' lack of it.

The teachers worked to embrace heterogeneity in STEM by including diverse viewpoints on science. Hattie discussed in her initial interview that she wanted to present a view of science that reflected her own identity as a non-white female, as well as the diverse identities of her students, which was not the experience she had as a science learner. Erika frequently proposed including non-Western viewpoints in the team's lessons. Erika had a strong commitment to showcasing indigenous knowledge as a legitimate source of science information and wanted students to learn science, not to be participants in a capitalist society, but to be prepared to critique dominant systems in society (Bang et al., 2012; Nasir et al., 2021; Paris & Alim, 2017). However, this view of embracing heterogeneous viewpoints did not always align with the teacher's work of supporting sensemaking. While they wanted to center others' diverse views, they often struggled to produce lessons that centered students' diverse sensemaking, instead building lessons that sequenced and structured all students to produce the same scientific model or explanation. In this way, students' diverse views and sensemaking were not seen as a legitimate source of learning (Carlone & Lancaster, 2024; Gonzales-Howard & McNeill, 2019; Windschitl & Calabrese Barton, 2016). This suggests that the teacher's goal of supporting sensemaking was motivated by recognizing the value of students' ideas as part of science learning, but was also limited by their ability to make space for diverse views as driving features of their classrooms.

While making space for non-Western views and providing them with a “rightful presence” in their science classrooms (Calabrese Barton & Tan, 2020), the teachers struggled to do the same for students' viewpoints. It wasn’t until the project-based climate change unit that the teachers were able to center their instruction on the local challenges their students' communities faced, while also providing students with agency to guide their learning. In this unit, the teachers grappled with new instructional arrangements that allowed them to attend to the diverse

sensemaking of their students while using science as a tool to support action towards justice in their students' communities (Philip & Azevedo, 2017). The teachers achieved their goals in ways aligned with Frame 5 (NASEM, 2025), with instruction that positioned students to envision sustainable futures and to act on current challenges related to climate change (Shamon et al., 2022; Tzou et al., 2021).

Lee and Grapin's (2025) framework provides a lens for examining the teachers' three goals, drawn from three eras of science education. They describe three eras of STEM education that approach equity and justice in different ways. These eras were drawn from literature spanning various time periods but continue to inform various aspects of teachers' work today. These various discourses inform the teacher's work and goals. The teacher's goal of access most closely aligns with the traditional approach in which scientists and educators defined what knowledge counts as science, with the goal of science education being to provide students with the specific content knowledge necessary to participate in future science careers. The teacher's second goal of sensemaking aligns with Lee and Grapin's description of the contemporary approaches of STEM education. During this era, as reflected in the Next Generation Science Standards (NGSS Lead States, 2013), students make sense of scientific phenomena and design solutions while building science and engineering practices to emulate the work of scientists. The teachers in this study spent the majority of their planning meetings discussing ways to attend to this structure of science classrooms. Finally, the teacher's third goal regarding justice most closely aligns with Lee and Grapin's description of future approaches to STEM education. In their proposed future approach, justice is promoted "as students explain societal challenges and design justice-centered solutions by leveraging multiple STEM subjects" (Lee & Grapin, 2025, p. 2257). The teachers worked toward this goal primarily in their climate change unit by featuring interdisciplinary learning and taking a problem-posing approach to education (Chen & Moore Mensah, 2022; Freire, 2000). Overall, I found that the teachers pulled from each era of science education as they developed their equity goals. In doing so, they were guided by

approaches with different aims. This resulted in their goals occasionally working at cross-purposes and required the teachers to either prioritize one goal over another or, in the case of the climate change unit, to find a unique set of pedagogical actions that allowed them to attend to each goal simultaneously through complex instruction. Taken together, these findings show that the teachers established goals that used traditional, contemporary, and future approaches to equity in science education, but struggled to find opportunities to achieve all three, frequently prioritizing access from a more traditional viewpoint of science education. To move towards future approaches to science education, Lee and Grapin (2025) argue that educators' beliefs about the goal of science must shift, as must epistemological shifts in the source of knowledge.

The literature on teachers' goals and how they address pedagogical dilemmas highlights the complexity of teachers' professional lives (Ball, 1993; Strom & Viesca, 2021). Teaching is full of “endemic uncertainties” (Lortie, 1975) that must be navigated, including those arising from organizational messages, teaching standards, and varying priorities among collaborating teachers (Allen & Heredia, 2021; Kelley & Finnigan, 2003; Wallace & Kang, 2004). Stories from teachers, including those in this study, often cite the limited capacity they feel to attend to initiatives and goals. The findings in this study suggest that teachers can accomplish attending to multiple goals, even when those goals seem to conflict, by designing instructional moves that account for the nuanced context of their lessons, units, and students. This outcome shows a counterpoint to the literature that describes how inherent goal conflicts, meaning goals whose outcomes are incompatible, are resolved by the abandonment of one or more goals (Gorges et al., 2022; Hutner et al., 2022; Segerstrom & Solberg Nes, 2006). In this study, the teachers experienced an inherent goal conflict between wanting to provide clear instruction that promoted information acquisition and wanting to design activities that allowed students to learn through grappling with uncertainty and engaging in sensemaking. Clarity and uncertainty were in conflict in multiple units of instruction, during which the teachers prioritized clarity. However, the

teachers shifted in their approach to their conflicting goals. They navigated this conflict differently during the climate change unit, in part due to the project-based unit's requirements, which foregrounded students' choices, as well as the contributions I made by prompting the teachers to consider more deeply their problem of practice. In the following section, I discuss how the teachers in this study shifted their practice and their views of their goals, thereby resolving some of the conflicts among them.

Shifting Practices and Understandings of Equity

By attending to the nuanced context of a pedagogical dilemma that emerged from classroom interactions, the teachers in this study were able to navigate multiple conflicting goals that they were previously unable to overcome. I observed during a collaborative planning meeting in their unit on climate change how the teachers surfaced their goals for students' sensemaking and issues of justice. The findings suggest that during the seemingly more complex unit on climate change, the teachers were able to foreground their goals of justice and student sensemaking and move beyond their typical prioritization of providing students with clear, accessible content instruction. This produced a shift in how the teachers planned and enacted lessons, how they understood the role of agency in students' learning, and how they viewed justice as being more than just a topic to teach.

I observed a shift in the teacher's planning work, reflected in their classroom enactments, from prioritizing clear, accessible instruction to providing more space for students to productively struggle with making sense of the content. This was a shift in the norms and routines of the teachers' planning work. In units prior to the climate change unit, when the teachers were planning lessons and evaluating various propositions for how to deliver the lesson, they typically chose those with the clearest set of instructions for science content. During the December planning meeting, midway through the climate change unit, when the teachers identified a shared dilemma of students not knowing how to make progress in their

group research, they initially proposed the same solution: to develop a clear set of instructions to guide all students. However, after having an extended discussion, the teachers instead identified that setting a single path of instruction for all students would foreclose on their goals of allowing students to choose different topics to research and of supporting productive sensemaking of climate solutions. This shift in the teacher's planning work allowed them to reinforce their commitment to promoting students' agency, reflecting their growing understanding of how student agency can support student learning.

The teachers also shifted in how they approached justice issues within their science classes. In prior versions of this climate change unit, the teachers spent most of the instructional time explaining climate change and having students reproduce a model of the greenhouse effect. This year, the teachers centered their goal of linking science and justice and shifted their view of teaching for justice. By organizing this climate change unit around students developing local climate solutions, they shifted the unit's focus from the science of climate change to the complex interconnections among climate work, politics, science, and society. Instead of explaining to students how issues of justice relate to science, the teachers placed justice at the center of students' work (i.e., students explored how to implement climate solutions in their own neighborhood to address problems and challenges in their community). By building on students' expertise of climate change and of the local area, the teachers positioned students to act as agents of change, working towards justice. This demonstrated a shift in teachers' views of justice in science education.

Mechanisms that supported teachers' learning

In exploring why the shifts to centering productive sensemaking, and to teaching for justice occurred, a few factors emerge as mechanisms that support them, reflecting the learning the teachers experienced. These factors included 1) the teachers' work on an ambitious instructional unit that aimed to integrate project-based learning, complex issues related to

climate change, and their three equity-oriented goals, 2) facilitated support that helped the teachers to make their pedagogical judgment more public and disrupted the normal routines of prioritizing access, and 3) collaborative exploration of teaching moves and strategies that supported students diverse learning needs through the use of productive struggle. I discuss each of these factors in turn.

Ambitious Unit Focused on Social Justice Science Issues

This study suggests that the inclusion of social justice science issues in the climate change unit was an important aspect that supported the science teachers' navigation among their equity goals. While in earlier units the teachers struggled to navigate multiple conflicting goals due to feelings of limited capacity, during their climate change unit, they were able to navigate their goals more successfully while also attending to additional complex features of the unit. By organizing this unit to be project-based, the teachers took up complex teaching approaches that have been shown to support students through culturally relevant instruction and sensemaking (Krajcik et al., 2021; Ramey & Stevens, 2026). Instead of acting to limit the teacher's capacity, the project-based unit structure helped them commit to their goal of sensemaking and explore instructional strategies that supported students' learning through open-ended problem-solving.

Additionally, the teachers made space to address the complex, integrated issues of justice, politics, and science in this unit on climate change (Windschitl, 2023). The data showed that earlier in the year, the teacher stated a goal to incorporate justice issues in their science classes, yet examples from how they planned and carried out lessons showed that the teachers typically taught about justice issues in the same way they taught about science content, ie, they told students about issues of justice and how they were related to science. This shifted once the teachers attended to the contexts of the climate change unit. They moved from teaching about climate justice issues to teaching with justice, positioning students with agency to explore

solutions of their choosing and, for justice, positioning students as experts who could recommend how solutions were carried out in their own neighborhoods. Morales-Doyle (2023) discussed the critical role that science education with a justice lens can play in addressing social challenges such as climate change by taking up Freire's (2000) generative themes, transdisciplinary science education, and the cultivation of critical consciousness. Similarly, Barton and Upadhyay (2010) have argued that teaching for social justice involves attending to science content knowledge and discourses, as well as positioning learners to take action on such issues as a form of empowerment. This study provides valuable examples of how a group of science teachers took up such calls for transformative science education. The findings here suggest that by focusing on local, meaningful teaching contexts for climate change, teachers were able to expand how they incorporated social justice issues into their courses while also reinforcing students' knowledge and sensemaking of the science of climate change.

The data from the case study of the teachers' planning meeting and dilemma-focused discussion provide a powerful example of how teachers' attention to the context of their work can open a seemingly un-navigable route to achieving their equity goals. Researchers have long emphasized the importance of attending to the context of teachers' learning in research, especially in the work of learning to transform education to be more equitable (Franke & Kazemi, 2001; Gutierrez, 2012; Shim & Thompson, 2024). Similarly, teachers' attention to the context of their content, students, and instructional practice is essential for developing their expertise (Konig et al., 2022; Patterson Williams et al., 2020; Shulman, 1986). Similar to those findings, over the course of this study, the teachers navigated a complex space among their goals, which tended to be in conflict, by surfacing the deeper context of their problems of practice and developing instruction that fit the specific learning goals of the unit.

Facilitated Support to Engage in Pedagogical Judgment

Another mechanism that supported teachers' learning was my facilitation of their conversations, which led us to engage in pedagogical judgment that disrupted the teachers' normal routines of prioritizing access. During the planning meeting within the climate change unit, I supported the teachers in spending more time discussing the dilemma they were all experiencing with students to identify the root causes of their problem of practice. While students were struggling to draw inferences from their research on climate solutions to describe how those solutions could be implemented locally, the teachers initially wanted to find a single clear instructional path to provide to all their students. However, through my collaborative prompting during their planning, we came to understand that students needed an opportunity to receive confirmation of their work and inspiration to move forward with their ideas.

This data suggests that the teachers, with my support in the form of probing questions and collaboration, were able to disrupt their typical pattern of dealing with goal conflict, ie, prioritizing their goal of clear, accessible instruction over their goal of creating opportunities for students to guide their own learning and sensemaking. The teachers re-examined their instructional practices and found ways to support students that maintained their agency. In noticing a dilemma during student during group work, in which students were struggling to organize their group work time to make adequate progress and finish by the end of the week, the teachers wanted to find a way to support students in making progress and guide them toward solutions, despite each group working on a different topic and set of problems. Initially, they proposed narrowing the scope of what students were allowed to work on and establishing guidelines for what students should complete each day to ensure each group was held accountable for finishing their work. Instead of settling on these solutions, which would have been the teacher's typical pattern of planning, prioritizing clear instruction to support students, I engaged the teachers with probing questions. My influence helped to shift the teachers from

their normal meeting routines. This slowed down the teachers' planning meeting. As I asked questions to help me understand the teacher's problem of practice, we were able to dig more deeply into the dilemma and uncover additional essential goals the teachers wanted to work towards. Instead of just wanting their students to finish the project on time, we surfaced that the teachers wanted students to feel more confident in their choices that they were making in their projects, they wanted students to see examples of other students' work, and they wanted to formatively assess which student groups were making progress and which needed more one-on-one support. These goals emerged from extended pedagogical discussions prompted by the clarifying questions I posed. These goals also aligned with the teacher's second equity goal of supporting student sensemaking. Literature on teachers' pedagogical discussions and collaborative learning points to the importance of taking time to deepen teachers' noticing of complex aspects of instruction and how teachers collaboratively refine their ability to align goals and pedagogical actions (Ball, 1993; Horn & Garner, 2024; Little, 2002; Patterson Williams, 2020). This study provides an example of how teachers refined their pedagogical judgment through exploring how to best attend to a problem of practice while reflecting on their equity goals. This extends the literature by showing how slowing down helped teachers interrupt their typical planning patterns and shift their attention to their equity goals.

Collaborative Exploration of Teaching Moves and Strategies

Finally, the data show that the teachers were able to attend to students' choices and creativity as prerequisites for their project-based climate change unit, and, collaboratively, we developed instructional moves to prioritize those goals. In designing this project-based unit, the teachers committed to organizing it so that each student group would work on a different climate change solution of their choosing and make creative leaps in deciding how to apply those solutions to local contexts. While their students were used to answering questions that could be answered directly from a text, this unit required them to make creative decisions about how to

apply information about a climate change solution in their descriptions of how it might be implemented in their neighborhood, a process they struggled with. Students sat with this uncertainty and asked the teachers for help choosing where to implement their solutions. The significant shift that led to this outcome occurred during their mid-unit planning meeting. The teachers made active plans not to provide students with answers directly; instead, they focused their instructional support on providing maps and graphs of local data and asked students to draw on their funds of knowledge about their neighborhoods to decide where and how to implement the solutions. This finding suggests that the teachers' commitment to their goal of supporting students' sensemaking was reinforced by their decision to use a project-based approach to their unit.

The teachers identified that students needed some form of accountable feedback to bolster them as they took academic risks (Cohen & Lotan, 2014; Strum, 1971) in choosing how to apply local climate solutions, and that students would benefit from seeing their peers' creative solutions and applications. The teachers decided to move away from telling students to follow a sequence of steps that would clarify what needed to be accomplished, since each student group was working on a different topic at a different pace. Instead, to promote student accountability, the teachers organized peer-feedback sessions at the end of each class to allow students to hear from each other, gain insight from each other's work, and for the teachers to hear which groups were making progress. This move maintained students' ownership of ideas in the classroom and helped teachers plan upcoming lessons, providing differentiated support for different groups. The teachers and I developed this routine to allow students to provide feedback to each other, rather than creating an instructional sequence that provided a single, clear route for students to follow. Students were thus held accountable to one another and learned from sharing with their peers while maintaining their own agency in exploring their chosen topics.

Teacher Learning

This study explores a few mechanisms that supported teachers in shifting both how they taught and how they understood how their equity goals interacted. By interrupting the normal routines of teachers' planning meetings, I posed probing questions that created discursive space for teachers to attend to the contextual factors shaping students' responses to the lesson. The creative and agentic requirements of the project-based unit reinforced the teachers' commitments to support student sensemaking. The teachers shifted from teaching about the links between justice and science issues to positioning students as active participants in their community, given the social justice issues at the heart of this unit. The ambitious work of teaching social justice science issues using project-based units that position students with agency and expertise opened up a space for teachers to learn and attempt new approaches to instruction.

In my theoretical framework, I described a learning mechanism drawn from situated learning theories that points to ways teachers refine their pedagogical judgment and reflect on those ideas in their practice within their community (Hall & Jurrow, 2015; Greeno, 2006; Horn, 2019). The data I presented show that the teachers shifted from prioritizing clear instruction as a means of access to designing supported learning opportunities that allow students to struggle and make sense of science concepts. They also shifted from teaching about the links between justice and science issues to also positioning students as actors in the process of using science to achieve justice-oriented social change. Researchers in science and math teachers' professional learning have long examined how teachers can resist change to both pedagogy and ideology (Rodriguez, 2004). This research and literature in this field point to the importance of attending to both the practices teachers use to pursue their equity-oriented goals and the ideologies that inform those goals (Allen & Heredia, 2021; Buehl & Beck, 2014; Gonzalez-Howard & McNeill, 2019). In this study, the three teachers established equity goals that focused primarily on changes they wanted to make to their pedagogy, i.e., how they took

action in their classes. They wanted to ensure they had clear, accessible instruction, to use better sensemaking routines, and to teach about the intersection of justice and science. They established their three goal statements as shifts they wanted to see in their pedagogical practice.

However, over the course of this study, the teachers shifted to also attend to their beliefs about equity and the ways they valued students' agency, sensemaking, and work towards justice. The teachers refined their ideological positions and understandings of the purposes that their goals served, particularly as they surfaced problems of practice during their climate change unit. During the planning meeting for this unit, the teachers and I explored the reasons students were struggling and the outcome the teachers ultimately hoped for. We discussed alternative pedagogical practices, which, in turn, opened the discussion to changes in beliefs about the purpose of science education and what teachers valued in science learning. By taking time to move beyond planning specific class activities and instead discussing the teachers' views of science, we shared our epistemologies and axiological views of science education with one another (Bang et al., 2016). Philip (2011) describes teachers grappling with ideologies as happening ‘in pieces’ with teachers developing more well-elaborated systems of thought over time and learning opportunities. So while the teachers engaged in learning and demonstrated shifts in their teaching practices, they also engaged in discussion that provided them with space to make sense of their ideologies around science education (Daniel et al., 2023; Salisbury, 2020). In this study, the teachers refined their ideologies about the role of sensemaking in their science classes. They moved from seeing sensemaking solely as students developing models of science concepts to also recognizing it as tied to agency and productive struggle as students made sense of complex issues of climate change in their local communities.

Limitations and Future Research

The contributions of this study were generated by the planning and teaching work of three high school biology teachers at a large public high school in the Pacific Northwest with a diverse student population. The experiences of these three teachers and the context of their school, curriculum, and students are not meant to be representative of the broader community of teachers or of students across the country (Hodgkinson, 2002). The findings presented in this study show a case of how the participating teachers grappled with their equity goals, how they navigated conflict among their goals as they planned lessons to meet their students' needs, and the impact that a uniquely structured unit of instruction had on their ability to attend to issues of equity and justice. More research across additional school settings and content areas, as well as research conducted by larger teams of teachers with different orientations to equity, would be helpful for understanding variations in how teachers navigate their goals and how unit structures in other content areas afford teachers the opportunity to take on novel teaching approaches.

As I shared in the Methodology section, the timeline of this research study was limited to the teachers' planning meetings over one semester. I conducted initial interviews in the last month of the prior school year, familiarized myself with the teachers' context, and began building relationships during this time. Over the course of the primary data collection period during the fall semester, I observed four units of instruction, including teachers' planning and classroom enactments. The final unit of the semester, the project-based climate change unit, served as a culmination not just for the students' learning over the course of the semester, but also for the teachers as a learning opportunity to realign their goals with their teaching practices, given the new structure the climate change unit provided them. The scope of this research was limited to this trajectory. While exit interviews showed a shift in how the teachers discussed their goals and the ways they approached their science teaching practices, I do not claim that the teachers' practices shifted permanently after the end of this study's period. One potential avenue for further exploration would be to see if the teachers adjusted their non-project-based units to

include elements of student choice and applied research in future years of instruction. Future research may examine the long-term impact of teachers' attempts to adopt new approaches. While this study explored how this group of teachers confronted conflict between their practices and their goals, others may examine the evolution of teachers' practices over the years, along with the shifting influences of initiatives and changes in participation in teachers' communities of practice.

In this study, I used a theoretical framework that situated teachers' learning within the community and the contexts of the participating teachers. From this perspective, I made the active decision not to analyze how the teachers' discussions about their goals and the planned lesson showed conflict with each other. During a planning meeting, the three teachers would sometimes disagree on how to design a lesson. Through discussion that revealed their pedagogical judgment, as I showed in my findings, they would often resolve these conflicts by identifying how the work aligned with their shared goals. However, sometimes their differences of opinion persisted, and the teachers would take different paths or defer to one or the other due to status, indifference, or other factors. I did not analyze these factors as part of this study, as they would require a theoretical and analytical framework focused on interpersonal conflict or social struggles for power and authority. Such variables are clearly worth studying, particularly in the context of teacher collaboration in professional settings. However, it was not the focus of this study. Instead, I narrowed this study to examine teachers' collective learning situated within the shared practices and approaches that emerged from their collaborative planning meetings. The analytical framework I used allowed me to understand how the teachers developed a community of practice with shared goals and enacted those goals through student-facing lessons.

Research Implications

This study suggests a few implications for both educational researchers and teachers regarding how science teachers navigate equity-oriented goals and how these goals can be pursued across different instructional contexts. First, teachers' professional learning goals are situated within broader discourses on what teaching is and what teachers' responsibilities are. These discourses often build from multiple frames and approaches that shift over time and over various conditions. Teachers navigate a complex discursive space that implies responsibilities to work towards different results, creating conflict among those goals. Further, goals and how teachers make sense of them are highly dependent on the day-to-day working conditions, such as district initiatives, colleagues' inputs, and students' needs. Thus, teachers' goals should not be assumed to be singular or unchanging. This study provides an empirical case study of how a group of teachers held a set of goals informed by various pedagogical responsibilities, how those goals shifted in priority over the course of multiple instructional units, and how they were able to successfully navigate conflict among their goals in light of a project-based unit that required attention to students' agency and issues of justice.

Second, the findings from this study suggest that teachers engage in complex pedagogical judgment talk as they work to make sense of their equity-oriented goals and enact them during collaborative planning meetings. These findings may be helpful to educational researchers examining how teachers work toward their goals when they do not explicitly state or reframe their work to foreground those goals. This study reveals that the participating teachers rarely began their collaborative planning meetings by revisiting their goal statements. Instead, the teachers frequently began discussions by offering propositions for pedagogical actions that revealed the goals they held for their upcoming lesson plans. Here, the propositions served to imply the goals while the teachers stayed close to the practical and logistical work of preparing a lesson. Their resulting episodes of pedagogical judgment around those propositions then indicated how they prioritized their goals and aligned them with their professional

responsibilities. While these discussions align with the multiple cases illustrated in the literature of pedagogical judgment (Horn & Campbell, 2015; Horn & Garner, 2022; Janis et al., 2020), this study provides a unique application of pedagogical discussions during future-looking lesson planning meetings among a group of colleagues, as opposed to the more typical retrospective discussions that make up the pedagogical discussion literature.

Finally, this study elevates the importance of social justice science issues and interdisciplinary project-based approaches in creating space for teachers to attend to their goals of equity and justice (Krajcik et al., 2021; Morales-Doyle, 2024; Windschitl, 2023) While the teachers held goals to support students' sensemaking and link science to issues of justice, they often worked towards these goals with the same set of principles and teaching approaches they used to deliver simple, clear, and direct content instruction. As they maintained this orientation during many of their units, they struggled to find ways to effectively center students' heterogeneous sensemaking or to position students to meaningfully grapple with relevant social justice issues in science. The science teachers in this study benefited from reorganizing their typical unit structure during the project-based, interdisciplinary climate change unit. Thus, they were able to attend to students' agency, local issues in which students could apply their funds of knowledge, and support students' sensemaking through creative means of expression. These findings suggest that other science teachers may similarly benefit from approaching science education from justice and equity-oriented lenses that make space for moving away from a focus on content and disciplinary core ideas. Teachers may need to take time to engage in discussion with collaborative peers to investigate what outcomes their goals are working towards, which goals are taking priority, and how classroom structures might be reorganized to attend to deeper purposes and multiple goals simultaneously. Further, to take on ambitious equity goals while also teaching complex justice-oriented topics, such as how to reduce the harms of climate change, teachers need support from peers and from the systems of teacher professional learning.

In Closing

I hope this dissertation provides an illustrative example of the complexities teachers face in working towards the goals of equity in science teaching. This study shows how the participating teachers drew on diverse, sometimes conflicting frames that address what teachers should do and how science should be taught. It was the responsibility of these three participating teachers, and their commitments to equity, that allowed them to continually reflect on their goals and how they aligned with their practices. Teachers are faced with overwhelming tasks and continuously work to meet the needs of their many students. Despite the complex work of day-to-day teaching, these teachers consistently added at least one, and often multiple, goals and novel strategies to their practice. Their work in designing and iteratively improving their climate change unit was essential in helping me, as a researcher, see how they were attending to justice.

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Appendix A: Pre-study Interview Protocol

Topic: Teachers' views of learning in a community of practice
Informant: Public middle school science teacher in PNW

Preamble: Thank you for participating in this interview with me today and welcoming me into your school community. I am excited to work with you all and build an understanding of how teachers think about collaborative learning and improving their practice.
We will start with some questions about learning as a teacher, then move on to questions about students' learning and your practice. I am also interested in hearing any examples you can provide about previous collaborative work you've engaged in.
I want to remind you that I am not here to judge your responses or evaluate you as a teacher, but instead, I want to understand your valuable insights as a teacher and learner. I would love to hear whatever ideas are coming up for you. Do you have any questions before we begin?
Would you mind if I record our conversation? At the end of the interview, you can let me know if there is anything you would like me to omit.

	Notes:
Demographics: First, some basic info about yourself. Research like this often wants to have a solid picture of who the participating teachers are. What subject and grade do you teach? How many years have you been a teacher, years in this school? What gender/pronouns would you like me to refer to you by? What ethnicity/race would you identify as? Are there any other identity factors you'd like me to record?	
1) How would you describe yourself as a teacher? a) What are your values as a teacher? What parts of teaching are most important to you? b) What goals do you work towards in teaching?	
2) Over the course of your career, after your initial teacher training program, what has learning and improving as a teacher looked like for you? a) Has learning been from formal PDs? b) Learning in the moment in class? c) Informal learning on your own time? d) PLCs?	
3) When collaborating with other teachers to improve your practice… a) What has worked? b) What barriers have you experienced?	

4) During formal or informal learning, what topics or lessons have you learned? a) What's been common or typical? b) What do you wish you had more experience with? Do you have any experience with educational research?	(optional)
Conceptual Resources: **The remaining set of questions will be around the big ideas that this school and Highline are grappling with, and how you draw on those ideas to learn and teach.** 5) The district is working on improving literacy rates and literacy instruction in the content areas. How are these efforts shaping your teaching? a) What has been communicated to you? b) What priority does it take in your day-to-day? c) What are you doing to support the district work? d) How does it impact your PLC, or staff meetings?	
6) What are your personal priorities and goals as a teacher? a) What do you want to get better at? b) What do you want to spend time on in PLCs? (i) Why that goal?	
7) Can you describe a typical PLC meeting? a) Who's involved and what do you each do? b) What structures or activities do you use, if any? c) What ideas are centered during meetings? d) How do these meetings impact your teaching?	(optional, prioritize c and d)
8) In my conversations with other teachers and district people, the goal of the literacy work or teachers' learning is to make schools more equitable. What does that word 'equity' mean to you? a) If you use 'equity,' what do you mean? b) What do other people mean by it? c) How would 'equity' show up in your class?	
9) Others talk about important things in science instruction as being student-centered, building off of students' FoK, focusing on relevant phenomena. How do you see that stuff fitting into your work of improving literacy in science?	
Is there anything you thought I might have asked about that you'd like to share?	

Appendix B: Post-study Interview Protocol

Topic: Teachers' views of learning in a community of practice
Informant: Public high school science teacher in PNW

Preamble: Thank you for participating in this interview with me today. And for letting me join you and your team over the last 8 months. Your work has helped me to build an understanding of how teachers think about collaborative learning and improving their practice.
In this exit interview, I wanted to ask you about a few goals that seem to be at the center of your work, as well as some lessons that played a large role in your planning work.
I want to remind you that I am not here to judge your responses or evaluate you as a teacher, but instead, I want to understand your valuable insights as a teacher and learner. I would love to hear whatever ideas are coming up for you. Do you have any questions before we begin?
Would you mind if I record our conversation? At the end of the interview, you can let me know if there is anything you would like me to omit.

Across the data I collected, I have seen that there are many goals and targets you are working towards, and that inform how you design lessons with your colleagues. a. First, do you feel that is true for you? b. How do you feel about the work of shooting for multiple goals at the same time?
One of the goals I have seen you all work towards is around **access to science content.** I've tried to summarize it as a statement: We want every student to be able to achieve the science content learning objectives. To do this, we must provide instruction that is clear, direct, and engaging. Do you feel this captures things that you are working towards? Would you like to change or emphasize any part?
Another goal is to **support sensemaking:** We want to support students' sensemaking skills by providing learning opportunities that cultivate creativity, agency, and the ability to explain scientific phenomena. Does this capture things you are working towards? Would you like to change or emphasize any part?
And lastly, I have noticed a goal around **linking science to issues of justice:** We want to present science in ways that are relevant to the contexts of our students' lives, connected to societal issues, and inclusive of diverse perspectives and ways of knowing. Does this capture things you are working towards? Would you like to change or emphasize any part?

When considering those three goals, how do you feel your daily practice balances each goal? Do you feel that any goal takes priority? Are there ways for one goal to conflict with another?
In your unit on climate change and the climate solutions project, I noticed these three goals were emphasized a lot. Was there something about this unit that you feel helped to you work towards your goals?
Lastly, is there anything about your work that you feel is important to be included in my research and findings?

Round 2 Exit Interviews

Preamble: Thank you for joining me again today and answering a few more questions. Today I wanted to follow up on a few findings that are emerging from my analysis of the day. I would like to share a few of them with you and get your ideas in response.

I want to remind you that I am not here to judge your responses or evaluate you as a teacher, but instead, I want to understand your valuable insights as a teacher and learner. I would love to hear whatever ideas are coming up for you. Do you have any questions before we begin? Would you mind if I record our conversation? At the end of the interview, you can let me know if there is anything you would like me to omit.

1. Over the course of this study, how do you feel you worked toward providing students with access to science content learning. Can you provide my any examples that you think best capture your work?
2. How do you feel you worked towards supporting students' sensemaking? Can you provide any examples that you think best capture your work?
3. How do you feel you worked towards justice over the last 6 months? Can you provide any examples that you think best capture your work?
4. What do you feel was the main focus of learning during the climate change unit?
5. During the climate change unit, we planned for a peer-feedback session as well as specific data and graph talks. How do you feel those strategies helped you work towards your goals?
6. The climate change project has been a unit you all have been working on over a few years. Over that time, what changes have you made to the project, and what specifically was unique about this year's implementation?

Appendix C: Classroom Observation Protocol

Classroom Observation:

Site:	Teacher:	Class:
Date:	Time:	Grade:
Communication Notes:		

Classroom demographics

Record the number of students in each category. These are based on the observer's interpretations of how the students present and can be confirmed by teacher and student discussion. Students will not be asked to identify.

Total number of students in class:
Asian:
Black:
Hispanic:
Middle Eastern
Native:
White:

Physical characteristics of the room

Seating arrangement and features

Background

Content and unique conditions

Other adults/students in the classroom:

Additional comments/information provided by teacher or students:

To be completed during the observation:

Time (min)	Teacher/student actions	Representations of Literacy, Ideologies or PD Learning	Other comments

To be completed after the observation:

Reflection:

Questions to follow up on:

Appendix D: Goals Reflection