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UNIVERSITY OF CALIFORNIA,
IRVINE

Science Teachers' Longitudinal Collective Sensemaking
of Equity-Centered Instruction

DISSERTATION

submitted in partial satisfaction of the requirements
for the degree of

DOCTOR OF PHILOSOPHY
in Education

by

Stephen R. Skoropad

Dissertation Committee:

Professor Hosun Kang, Chair

Professor Elizabeth van Es

Professor Elizabeth Peña

Assistant Professor Symone Gyles

2026

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- Analyzed data to inform programmatic changes promoting equity in teacher education
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Science Curriculum Specialist

Green Dot Public Schools, Los Angeles | Jul 2018 – Jul 2020

- Developed NGSS-aligned physics curriculum and professional development for 15+ school sites
- Coached teachers and department chairs in curriculum implementation and instructional practices
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Science Department Chair

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Hollyhock Leading Fellow

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Hollyhock Fellowship

Stanford University | Jul 2016 – Jun 2018

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- Participated in video-based peer feedback cycles with educators nationwide

11th Grade Physics and Robotics Teacher

Ánimo Leadership High School | Aug 2012 – Jun 2018

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- Co-founded inclusive robotics program (~50% female enrollment)
- Differentiated instruction to support multilingual learners and students with diverse needs

FIELD OF STUDY

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- ATE (2024): *Theorizing Teacher Educators' Noticing Practices with Data for Improvement*
- NARST (2024): *Using Historical Storytelling to Amplify ML Voices in Science*
- AERA (2023): *Enacting Racial and Social Justice in Teacher Preparation*
- ICLS (2022): *Locating as a Temporally-oriented Practice for Data Noticing*
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Abstract of the Dissertation

Science Teachers' Longitudinal Collective Sensemaking

of Equity-Centered Instruction

by

Stephen Skoropad

Doctor of Philosophy in Education

University of California, Irvine, 2026

Professor Hosun Kang, Chair

Despite the general consensus that teachers' learning of justice-centered instruction necessitates well-guided professional learning experiences across an extensive period of time, extending beyond one-shot professional development (PD), there are currently very few empirical studies that provide insight into teachers' learning processes. This longitudinal qualitative case study explored the collective ideological sense-making processes of high school science teachers as they engaged in a cycle of co-designing, enacting, revising, and re-enacting an equity-centered unit over 2 years. The context was a long-term research-practice partnership project between a university and a progressive local school district that was committed to promoting equity, justice, and civic engagement. The participants were six high school biology teachers, all members of a co-design team, on one of the five teams in the larger project. The data consisted of 95.3 hours of video-recorded small-group team meetings and whole-group PD footage, 12 hours of individual interviews, and teacher-developed unit artifacts. Using both pedagogical judgement (Horn & Garner, 2022) and cooperative action (Goodwin, 2018) as the analytical lens, the teams' collective sense-making processes were traced over 2 years in context. The research questions

asked: (1) What were the salient shifts in the planned pedagogical actions of the co-designed unit between the first and second year of the partnership project? (2) How did the team's discourses and decision-making processes for equity-centered science instruction evolve over the course of 2 years? and (3) How did the team's shift in pedagogical judgment relate to the semiotic resources presented in the professional development? The findings highlighted shifts in the team's collective pedagogical actions, decision-making language, and ideological stances over the course of the 2-year partnership, with more prominent shifts taking place at the end of Year 1 and start of Year 2, when the team had come to a shared responsibility, resulting in the team drawing from semiotic resources presented during shared professional learning experiences.

Keywords: equity-centered science teaching, teacher sensemaking, ideologies

Chapter 1: Introduction

Over the past 20 years, research has highlighted the systemic injustices within science education and their roots in Eurocentrism (Calabrese Barton & Tan, 2019; Kang & Zinger, 2019; Ladson-Billings, 2006; Mensah & Jackson, 2018). These roots have long privileged dominant cultural knowledge through curriculum, state standards, and teaching practices, perpetuating the view that the construct of science education is objective and politically neutral (Bang et al., 2013; Kang & Zinger, 2019). On the frontline of these issues are teachers and curricula, which hold the power to either maintain or disrupt these dominant ideologies (Bang & Bricker, 2021; Kang & Nation, 2023; Morales-Doyle, 2017). Unfortunately, studies have found that, historically, science teachers have struggled to enact contemporary forms of equity and justice in their classrooms (Bianchini et al., 2015; Sengupta-Irving et al., 2021). In-service teacher professional development (PD) has been used to support their sensemaking processes through this work (Adah Miller et al., 2023; Marco-Bujosa et al., 2023; Steele & Jeong, 2023).

Over the past 20 years, research has framed PD as creating spaces where teachers can engage in opportunities to learn about equity-centered instruction that result in changes in pedagogical practices (Bancroft & Nyirenda, 2020; Sleeter, 2017). Here, studies that have analyzed these spaces have foregrounded the importance of key learning experiences or short-term sensemaking processes (Adah Miller et al., 2023; Crabtree & Stephan, 2023; Damjanovic & Ward, 2023; Gargroetzi et al., 2021; Picower, 2011). The focus of these studies has been on how key learning experiences can shift or change teachers' practices, or, more importantly, what makes for strong PD. To this end, researchers in science education have developed frameworks for teachers, school leaders, researchers, and teacher preparation programs that outline essential

tenets for science instruction aimed at promoting equity and justice (Marco-Bujosa et al., 2023; Morales-Doyle et al., 2021; Sheth, 2019).

Some studies have elaborated on these themes by providing images of contemporary science teaching practices in classroom settings (Calabrese Barton & Tan, 2019; Kang & Nation, 2022; Morales-Doyle, 2017; Tzou et al., 2021). Despite the emerging nature of long-term collective sensemaking (Daniel et al., 2023; Penuel et al., 2012), short-term, moment-to-moment sensemaking has been the primary focus of the existing robust studies (Crabtree & Stephan, 2023; Damjanovic & Ward, 2023). Here, sensemaking has been understood through teachers' noticing practices (van Es & Sherin, 2008) for both preservice and in-service teachers. At the same time, others (diSessa & Sherin, 1996; Hall, 1996; Philip, 2011) have analyzed the ideologies that individual teachers hold and use to make sense of their social world, and which inform their daily pedagogical decision-making (Horn & Garner, 2022). A common trend in such studies is to move beyond teachers' observable actions and to conceptualize sensemaking within the socially constructed frames individuals hold (Philip, 2011). As such, researchers have theorized that shifts in teachers' sensemaking are observed not only in their pedagogical actions but also in the discursive language they use to rationalize those decisions (Davis & Palincsar, 2023).

However, less understood are the long-term sensemaking processes that teachers engage in within these spaces through the co-construction of a curriculum that results not only in shifts in practice but also in the decision-making processes behind them (Daniel et al., 2023). It is here that the present study is situated. The aim was to examine how science teachers collectively engage in sensemaking equity-centered science instruction within the context of a participatory design research project (Bang & Vossoughi, 2016) between a university and a local school

district. In this project, 20 middle and high school science teachers worked in small co-design groups with fellow teachers who taught the same subject (e.g., high school biology). Employing a longitudinal, qualitative case study approach (Huberman, 2014), I analyzed how one of the groups (the biology co-design team) expanded their ideologies of re-centering, drawing on knowledge foregrounded in the science classroom as a result of their continued interaction with a PD setting.

To provide insight into the processes of teacher sensemaking of equity-centered science instruction and knowledge foregrounding, I analyzed various qualitative data, including video recordings of teacher co-design meetings, classroom observations of the co-designed unit, and semistructured interviews conducted at four points over 2 years. The following research questions (RQs) guided the analysis:

RQ1: What were the salient shifts in planned pedagogical actions of the co-designed unit between the first and second year of the partnership project?

RQ2: How did the team's discourses and decision-making processes for equity-centered science instruction evolve over the course of 2 years?

RQ3: How did the team's shift in pedagogical judgment relate to the semiotic resources presented in the professional development?

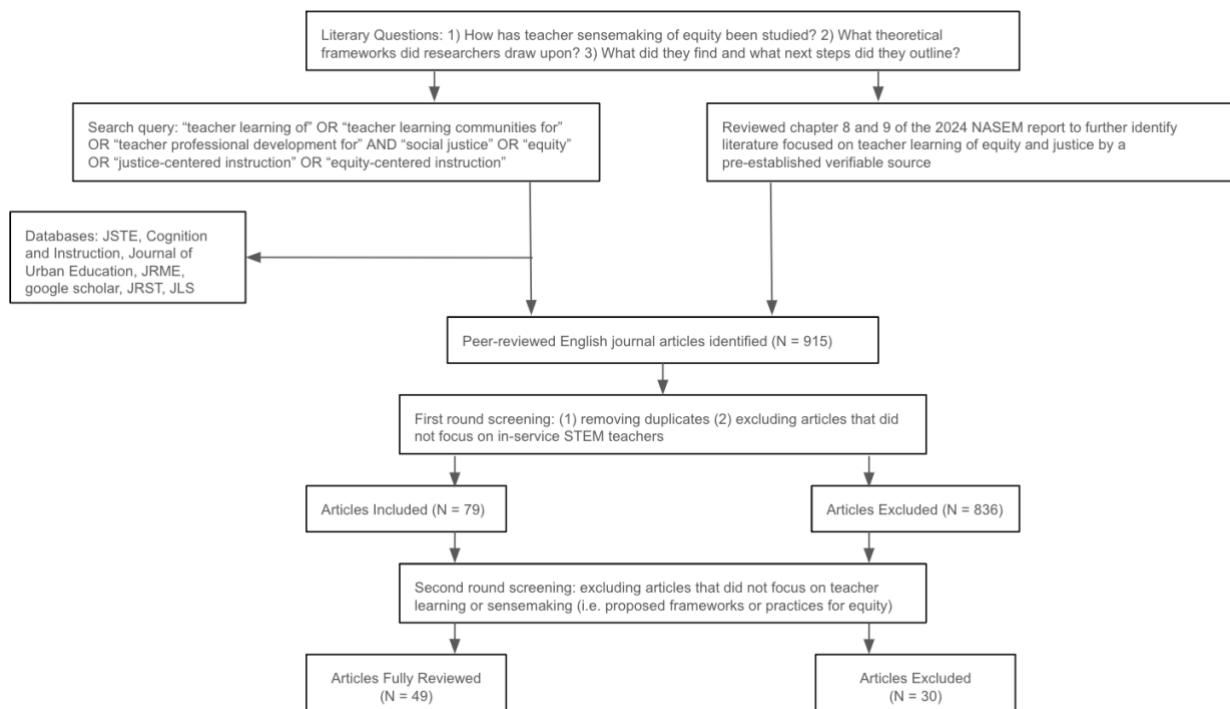
Chapter 2: Literature Review

Introduction

In this literature review, I used a PRISMA (Moher et al., 2009) methodological approach to identify relevant literature focused on understanding STEM teachers' sensemaking of equitable and just instruction (see Figure 1). Three questions guided this inquiry into the literary analysis: (1) How has teacher sensemaking of equity been studied? (2) What theoretical frameworks have researchers drawn on? (3) What did they find, and what next steps did they outline?

Figure 1

PRISMA Model Outlining Processes Taken to Identify Relevant Literature



In particular, I used six high-impact databases: (1) *The Journal of Science Teacher Education*, (2) *Cognition and Instruction*, (3) the *Journal of Urban Education*, (4) the *Journal for*

Research in Mathematics Education, (5) the *Journal of Research in Science Teaching*, (6) the *Journal of Learning Sciences*, and (7) Google Scholar. Across these databases, I identified relevant literature using the following criteria: (1) it was focused on in-service STEM teacher sensemaking, and (2) it explicitly attended to the constructs of equity and justice. Additionally, the literature review was limited to studies conducted within the past 30 years. It is important to note that during the initial stages of the literature identification process, I conducted a broad search to examine how teacher sense-making has been studied. This was due to the many ways in which sense-making and learning have been defined across STEM research. Toward this end, I analyzed titles and abstracts that explicitly attended to *teacher sensemaking* (synonyms included *teacher learning*, *teacher professional learning communities*, and *teacher professional development*) and *equity* (synonyms included *justice*, *social justice*, *justice-centered instruction*, and *equity-centered instruction*). This yielded 615 studies. In addition, Chapter 9 of the NASEM (2024) report has been identified as a verifiable source for identifying peer-reviewed literature that explicitly focuses on STEM teacher learning of equity and justice. This chapter covers about 290 pieces of literature, which were also reviewed as part of this analysis.

The first round of screening involved identifying literature that focused on in-service teachers and removing duplicates. The rationale for isolating preservice teachers' (PSTs) learning from in-service teachers' learning was the contextual and experiential differences between the two groups. PSTs have minimal to no pedagogical experience in the K–12 setting (as educators); as such, teacher preparation programs are established spaces designed to support teacher learning (Dyches & Boyd, 2017). Over the last 20 years in particular, these programs have made a concerted effort to generate equitable and just teachers who can foster inclusive spaces for all students (Morales-Doyle et al., 2021). Comparatively, in-service teacher learning

for equity and justice brings with it higher levels of variability due to the diverse years of teaching experiences individuals possess, the sociopolitical environment of their schools and districts, the prior professional training individual teachers have participated in, and the context of the professional learning experiences (Horn, 2007). Unlike teacher preparation programs, in-service teacher learning is not a well-established system; thus, perceptions and receptions towards it vary by teacher, school, and district (Damjanovic & Ward, 2023). For these reasons, this literature review excluded PST-based studies, and when I refer to teacher learning, I mean in-service learning. Through this screening process, 79 articles were identified as relevant to STEM in-service teachers' learning about equitable and just instruction.

In the second round of screening, the aim was to differentiate literature that focused on establishing a salient framework and on studying teacher enactment of equitable and just pedagogical instruction (ex. Kang & Nation, 2023; Morales-Doyle, 2017) with teachers' sensemaking processes of these constructs (ex. Daniel et al., 2023; Scott & Louie, 2024). Among the 79 pieces of literature selected, 30 were centered on making the practices and actions of equitable and just STEM instruction salient. While these studies illuminated what equitable and just STEM education can look like in the classroom, they did not centralize teachers' learning processes in achieving this goal. For this reason, these 30 studies were excluded from the full literature review. After this process, 49 pieces of literature were reviewed and analyzed, with a focus on addressing the three guiding questions above. The aim was to comprehensively analyze the field's understanding of STEM teacher sensemaking of equity and justice.

Purpose of This Literature Review

Science education in the United States has historically continued to focus on students' mastery of a pre-established body of knowledge, which is upheld as objective, factual, and

politically neutral (Mensah & Jackson, 2018). Paramount to this focus is students' acquisition of this knowledge and assimilation into White Eurocentrism, which perpetuates educational inequities (Bryan & Atwater, 2002; Johnston et al., 2011; Madkins & Nazar, 2022). Mensah and Jackson (2018) defined this centralization of Eurocentrism as configuring "science as a White property," illuminating its "inherent exclusiveness and alienation of people of color" (Kang & Zinger, 2019, p. 825). This centralization foregrounds Western modalities and White-European culture as normative, while delegitimizing the knowledge and experiences of historically marginalized communities within science education (Bang et al., 2013; Kang & Zinger, 2019). National and state standards and assessments focus on a rigid, pre-established set of knowledge grounded in Eurocentric norms (Bang et al., 2013; Warren et al., 2020). Here, discourses, pedagogical practices, and activities presented in the traditional science classroom disincentivize students from leveraging their powerful history and lived experiences, instead encouraging the acquisition of power-laden cultural norms, unfairly privileging certain students (White, heterosexual, with English as a first language) over others (females, racially and culturally historically marginalized or linguistically marginalized students) (Bang & Medin, 2010; Barton & Tan, 2019; 2018). Equity and justice work focuses not only on ensuring that all students succeed academically, but also on attending to the disruption of science as a White property (Davis & Stephens, 2022; Mensah & Jackson, 2018).

While disruption must happen at all levels of the educational system for equity to be fully realized, teachers are uniquely positioned in their roles with students to perpetuate or disrupt these dominant ideologies (Penuel et al., 2020). Unfortunately, science teachers are products of this Eurocentrist science educational system and, as such, without proper training are inclined to perpetuate it (Bancroft & Nyirenda, 2020). Examples of this can be found in multiple studies,

such as Sheth's (2019) analysis of teachers' conceptualizations and practices. Sheth (2019) highlighted the work of three teachers deemed social justice-focused by district leaders, only to find upon observation that two were racially avoidant and struggled to disrupt traditional classroom power hierarchies. Here, the teachers' "reluctance to grapple with race and racism served to flatten the ideas and experiences of Students of Color" (Sheth, 2019, p. 53). Similarly, Borgerding and colleagues (2023) studied 86 secondary science teachers in Ohio and their perceived enactment of climate justice education. The authors found that many teachers avoided discussing racial injustice in climate change discussions, prompting researchers to emphasize the importance of climate justice education.

As such, supporting teachers' understanding and enacting equitable and just science instruction involves shifting their practices and fundamentally evolving the ideologies that shape how they reason through their instructional decisions (Hall, 1996; Horn & Garner, 2022; Philip, 2011; Picower, 2011). Researchers and educational leaders have attempted this through equity- and justice-centered PD and teacher professional learning communities. In doing so, they have found positive impacts on teachers' learning of equity-centered instruction through their engagement in activities, structures, and resources on equity-centered teacher learning (Adah Miller et al., 2023; Crabtree & Stephan, 2023; Damjanovic & Ward, 2023; Gargroetzi et al., 2021; Picower, 2011). Notably, there have been inconclusive findings regarding the relationship between teachers' learning in equitable instruction and professional learning communities, highlighting the need for further studies to explore the relational role of teachers within this learning process (Horn, 2007; Horn & Garner, 2022). Furthermore, this literature review seeks to illuminate the methodological and theoretical approaches researchers have taken to understand teachers' sensemaking of equitable and just instruction. I achieve this by illustrating the

prominent and emerging approaches to studying teacher sensemaking, while highlighting the areas where further research is needed.

Defining Teacher Sensemaking

“There is no single agreed definition of sensemaking” (Brown et al., 2014, p. 266). It is for this reason that researchers have come to analyze teacher sensemaking through varying lenses (i.e., noticing, ideologies, pedagogies, etc.) with a common throughline of understanding the processes that they undergo to navigate and understand their school and classroom settings (diSessa & Sherin, 1996; Greeno, 2006; Hall, 1996; Odden & Russ, 2018; Philip, 2011). This navigational process has been conceptualized and studied as individually-centric, focusing on the teacher’s cognitive shifts (diSessa & Sherin, 1996; Hall, 1996; Philip, 2011; Sherin & van Es, 2005; van Es & Sherin, 2008), as well as through a sociocultural and collectivist perspective (Greeno, 2006), analyzing the contextualized moment-to-moment interactions (Scott & Louie, 2024). The inherently complex and messy nature of sensemaking has enabled diverse analyses, illuminating teachers’ knowledge and experiences in a given moment as they make sense of their social world.

From an individual and cognitive perspective, researchers have examined teachers’ noticing practices regarding how they frame students and make instructional decisions (Sherin & van Es, 2005; van Es & Sherin, 2008). This involves analyzing how teachers: (1) *attend*, or what they find essential, (2) *interpret*, or how they assign meaning, and (3) *respond*, or how they react to students’ actions. Similarly, researchers have focused on ideologies, which refer to the mental frameworks or concepts that individuals “deploy to make sense of, define, figure out the way society works” (Hall, 1996, p. 26). These concepts are focused on “systematically connected ways of getting information from the world” (DiSessa & Sherin, 1998, p. 1170). Often referred

to as mental frameworks or concepts that “stabilize a particular form of power and domination” (Hall, 1996, p. 27) or challenge the status quo, they can also be called “naturalized axioms” (Philip, 2011, p. 302) that stem from a societal level of shared meaning. This sharedness has been a focus for the collectivist lens, where researchers have drawn upon sociocultural learning theories, moving the analysis of sensemaking beyond an individual’s cognitive domain and centering on its socially collective and contextual nature (Engestrom, 2011; Engestrom & Saninno, 2021; Greeno, 2006). Here, researchers have analyzed elements of discursive conversations to shed light on this shared meaning-making process (Penuel et al., 2022). Researchers have referred to these forms of analysis as *situative learning* (Greeno, 2006).

Essential to this understanding is the notion that teachers’ sensemaking of equity and justice requires an ideological analysis, as this can add to the sociopolitical domain surrounding education and schooling (Engestrom & Saninno, 2021; Horn & Garner, 2022). This need stems from the “historically accumulating structural tensions” (Engestrom, 2011, p. 609) between non-traditional and traditional instructional practices (Horn & Garner, 2022). In STEM education, equitable and just practices are rooted in a disruptive ideology that directly opposes the maintenance of Eurocentric norms (Engestrom & Sannino, 2021; Morales-Doyle, 2017; Sengupta-Irving et al., 2021). As such, when teachers engage in sense-making processes focused on equity and justice within STEM instruction, they navigate these conflicts and dilemmas (Engestrom & Sannino, 2021). Here, dilemmas and conflicts, which are ideologically rooted and collectively decision-based, emerge from incompatible evaluations and lead to either the reproduction of the dilemma or to its resolution (through submission to the majority) (Billing et al., 1988; Engestrom & Sannino, 2021; Vuchinich, 1990). As such, for teachers to enact equitable and just teaching pedagogies, they must navigate deficit perspectives of students,

families, and communities, examine and address systemic injustices, and disrupt dominant discourses and narratives to create classroom spaces that sustain all students (Paris, 2012).

The complexity of equitable and just teacher sensemaking is supported by how researchers have built upon the previously mentioned sensemaking frameworks to conceptualize this sociopolitical domain. Louie and colleagues (2021) highlighted the need for further research to explore the sociopolitical domain of teacher noticing and to expand upon the equitable application of the *attend, interpret, and respond* (AIR) framework (Hand, 2012; Mercado, 2017; Roth et al., 2014). They proposed the FAIR framework, which also incorporates the concept of *frames*. They hold that even those frames considered neutral carry political power and positioning with them. The authors drew on Critical Race Theory (CRT) to highlight that even seemingly neutral political frames carry implicit racial hierarchies. Their study illustrated the application of the FAIR framework using Oscar, a university mathematics instructor who identified as a Latino male and who served a predominantly Latino community and institution. Their findings highlighted how using the FAIR framework allowed the researchers to attend to Oscar's anti-deficit noticing practices. Similarly, in an earlier study by Rosebury and colleagues (2016), the researchers built upon the noticing framework to construct interpretive power. Like noticing, interpretive power highlights the power and positionality within teachers' interpretation of classroom events, where power, race, and opportunity for learning play out.

Similarly, Philip's (2011) *ideology in pieces* framework illuminated the inherent messiness and contradictory nature of ideologies, where individuals and groups can express seemingly inconsistent statements across different contexts without being aware or troubled to attend to them. As such, the emergence and observation of these naturalized axioms can be seen through discursive conversations between individuals as they attempt to make sense of problems

or issues within the social world (diSessa, 1993; Philip, 2011). These ideologies stem from systemically rooted, naturalized axioms, or concepts held as *common sense*. Philip (2011) used an example: “My Asian kids do so well! They have been here for less than a year and ended up at the top of my class. Amazing!” Here, Philip (2011) examined the racial application of blame and fault, where racial categorization may be used to assign traits and homogenize the experiences of entire groups of students. Teachers draw upon these socialized experiences, in which they acquired naturalized axioms rooted in dominant ideologies, to make sense of sociopolitical issues, such as the one mentioned above.

Furthermore, while these naturalized axioms are part of an individual’s everyday knowledge, sensemaking involves the intersection of these naturalized axioms with formal knowledge (Munson & Dyer, 2020; Odden & Russ, 2019; Philip, 2011). An individual’s formal knowledge or, as DiSessa and Sherin (1998) discussed, naturalized axioms become secondary explanatory drivers to the expertise-based knowledge as an individual’s expertise expands. In other words, through experience, it is possible to override or reroute the knowledge base individuals draw upon as primary drivers of explanations.

From this perspective, knowledge rooted in either naturalized axioms or expertise is a product of social interactions in which ideologies are shared and accepted, perpetuating or disrupting culturally dominant systems of thinking. Critical to this notion is that when we apply *ideology in pieces* to science teachers’ sensemaking of educational issues, this expertise-based knowledge is a product of the social interactions they have had as part of their membership in the institution of education (Lampert et al., 2010). These experiences may include, but are not limited to, pre-service preparation programs, certification programs, and in-service PD, all of which involve social interactions that shape the expertise-based knowledge teachers draw upon

to sensemake (Philip, 2011). These social interactions are part of professional learning experiences in which ideologies that perpetuate or disrupt culturally dominant systems are given merit and collectively taken up by teachers (Sheth, 2019).

Daniel and colleagues (2023) examined the interaction between ideological sensemaking and social interactions among teachers during PD. The authors focused on teachers' ideological re-articulation through their participation in this PD, involving their discursive conversations in which they navigated the inherent tensions between naturalized axioms rooted in dominant systems of thought and expertise-based knowledge gained through the PD. The authors highlighted the interplay between individual teachers' ideological cognition and its shaping through social interactions. Seemingly, during these momentary interactions, there is an interplay between micro-level interactions and the macro-level systems of thought that teachers use to rationalize their decision-making processes (Horn & Garner, 2022). Teachers collectively navigate contradictions that arise from naturalized axioms to create innovative practices (Engestrom and Sannino, 2011; Philip, 2011; Scott & Louie, 2024). Similarly, Scott and Louie (2024) illustrated this relationship between micro-, meso-, and macro-level systems of thought in their *nested layers of activity* model. Here, they highlighted how teachers draw on ideologies rooted in meso- and macro-level systems of thought during these moment-to-moment interactions to make sense of their social worlds.

While the literature has taken numerous approaches to analyzing teacher sensemaking, it is apparent that there is no one singular way to understand teachers' sensemaking of equitable and just instruction. We can see from these studies that sensemaking is not limited to an individual's cognitive processes but can also emerge collectively during social interactions (Lobato et al., 2012; Walkoe & Luna, 2020). Critical to this notion is the context in which these

moment-to-moment interactions occur, including, but not limited to, the people, activities, structures, and organizations that comprise the space in which these events unfold (Scott & Louie, 2024). For this purpose, it is crucial to understand how PD and professional learning communities have been utilized to support the sense-making processes detailed throughout this section.

The Role of the Professional Learning Setting in Understanding Teachers' Sensemaking

For in-service teachers, PD settings have served as a defined context for learning equitable and just instruction (Sleeter, 2017). The primary source of data for the reviewed studies used either PD or a professional learning community for contextual analysis. Here, the primary methodology for collecting sensemaking data was video-recorded conversations between teachers nested within the professional learning experience (Scott & Louie, 2024). To understand the sense-making processes that teachers engaged in, many studies (Kang, 2022; Sengupta-Irving, 2022) employed a case study approach using a group of teachers or analyzed the discursive conversations of a single professional learning community. Furthermore, the researchers who conducted these studies (Kang & Zinger, 2019; Louie, 2016; Rosebery et al., 2016) isolated their data into episodic moment-to-moment interactions to ascertain trends and patterns across conversations. This has allowed researchers to contextualize these interactions and draw correlations between elements of the professional learning setting, people, and structures to understand shifts in teachers' conceptualization (Adah Miller et al., 2023; Crabtree & Stephan, 2023; Damjanovic & Ward, 2023; Gargroetzi et al., 2021; Picower, 2011).

Horn and Kane's (2015) comparative case study analysis offers an example of this. These researchers analyzed the relationship between math teacher work groups and opportunities for professional learning. To do this, they analyzed three different teacher work groups over the

course of a year, each located in the same district and participating in the same professional learning experiences. The authors found that, through these conversations, more accomplished teachers, i.e., those with greater expertise in ambitious teaching practices, had richer and more instructionally focused conversations that supported a greater sensemaking. However, often (though not always), these were more veteran teachers, while novice teachers tended to focus more on behavioral issues, which could limit their overall learning and growth. Horn and Kane (2015) highlighted the importance of PD coordinators and planners considering these findings when developing learning experiences, as expertise plays a significant role in growth and sensemaking. Their study illustrated the connections among individuals in these spaces and how they shaped participants' overall learning experiences.

On the other hand, Goode and colleagues' (2021) research examined teachers' engagement with and learning about race and equity within the context of computer science (CS) education PD. The focus on CS stemmed from the field's long-standing, dominant beliefs about gender, race, and culture. The findings from this study highlighted three components within PD that may support teachers in their learning and overcoming racial avoidance. The first was the need to complicate colorblind discourse, as Goode et al. (2021) highlighted a disagreement between teachers that ended in one teacher surrendering to the ideas of another, a dynamic resulting from school-based initiatives that promoted conflict avoidance. Instead, the authors concluded that it is essential to embrace these instances within PD experiences. The second highlighted the centering of race within the curriculum, with the authors stating, "centering teacher learning about race within the context of curricular lessons can open discursive space for teachers" (Goode et al., 2021, p. 388). An example they highlighted that emerged within the PD was when the facilitators highlighted teachers' avoidance of teaching a lesson involving race.

The third component was teacher agency among returning members. Goode and colleagues (2021) explicitly stated that the returning teacher's ability to attend to racial avoidance implied participatory agency within this context. Furthermore, teachers' relationships with each other and new members were a leverage point for shaping the sensemaking conversation.

The Relational Element Between Teachers Within the Professional Learning Setting

While activities play a central role in teachers' sensemaking processes within the context of PD, relationships among teachers have been identified as equally, if not more, influential in sensemaking processes (Horn, 2007). This is in part due to professional learning experiences that focus on developing teachers' instructional practices for equity and in part due to disruptive outcomes, which can lead to teachers developing "feelings of isolation, blame, and burnout" (Scott & Louie, 2024, p. 546). Teachers' collective groups hold tremendous power in shaping teachers' understanding of these disruptive practices, as they serve as "safe havens" and "sacred spaces" (Scott & Louie, 2024, p. 546). For this reason, researchers have analyzed these social interactions and their role in teachers' sensemaking processes. To explore teachers' collective sensemaking within the context of professional learning experiences, researchers must understand the experiences and relationships participants bring to this space (Goode et al., 2021; Sengupta-Irving et al., 2021).

Penuel and colleagues (2012) conducted a quantitative study analyzing the role of teacher interactions in students' learning processes during writing instruction within the context of a long-term PD series. To do this, the authors conducted a social network analysis to measure the social influence of teachers' interactions on teachers' understanding of writing practices. A significant component of this work stemmed from the levels of participatory engagement by teachers within professional learning spaces, which directly impact the changes and alignment in

their practices with what the PD is promoting (Cohen & Hill, 2001). The findings from this study supported the conjecture that social interactions within organized PD can directly and indirectly influence teachers' perceptions and practices. Furthermore, the duration of PD and the relationships between teachers may play a role in shaping these practices. From a sociocultural learning perspective, a teacher's expertise influences such social interactions by posing knowledge that others seek. By providing that information to the seekers, individuals tend to align their understanding with the presenter (Brown & Duguid, 1991; Penuel et al., 2012; Tyre & von Hippel, 1997). However, these social interactions and relationships can be fraught with tensions, especially when the sensemaking processes involve issues of race, power, and positionality.

Sengupta-Irving and colleagues (2021) explored the collective sensemaking process teachers engaged in during a PD learning experience that centered on the heterogeneity of knowledge within STEM. They framed the focus of this analysis on the emergence of racial ideologies within teachers' discursive conversations that highlighted micro-contestations and microaggressions between educators. Notably, the authors framed the criticality of this work as disrupting racial avoidance in teachers' professional learning spaces, as a necessary means for unlearning and relearning constructs related to race in the STEM classroom. The authors drew upon data from a nine-day PD seminar for high school teachers who attended to discuss heterogeneity within STEM classrooms. Twelve teachers participated in the workshop, of whom four were selected as focal teachers for this study. The specific event the researchers used lasted over an hour, and they analyzed it in detail. Here, Sengupta-Irving and colleagues (2021) delved into the ways that racial-ideological micro-contestation made a particular teacher of color vulnerable when discussing heterogeneity within STEM, ultimately leading to insults by teachers

who were part of the dominant culture. In other studies, the dilemmas and conflicts that emerge as teachers navigate this work have not been as explicitly foregrounded as they were here. As Engestrom and Sannino (2011) illustrated, the tensions and dilemmas that emerge as teachers navigate equity and justice perpetuate or disrupt dominant systems of thought. In this case, Sengupta-Irving and Macias (2021) demonstrated how teachers target colleagues who push back against these dominant narratives.

The findings from these studies have highlighted the critical role of PD in shaping both individual and collective teacher sensemaking processes related to equity and justice. Researchers have explored how teacher sensemaking unfolds within these spaces, emphasizing the influence of activities, structures, and relationships on this process. At the same time, these studies have revealed gaps in the existing literature, particularly regarding the long-term nature of teacher sensemaking through ongoing participation in PD. Additionally, further research is needed to examine the relational dynamics between teachers within these settings and how these relationships contribute to or hinder sustained engagement with equity-focused practices.

Implications for Future Research

Promoting equity within the classroom goes far beyond just implementing specific practices; it involves teachers being explicit in their attention to students' identities, the systemic injustices they face, and the power hierarchies within the schooling structure (Madkins & McKinney de Royston, 2020). For this reason, professional learning settings (i.e., PD and professional learning communities) need to move beyond simply supporting the implementation of practice (Horn & Garner, 2022; Morales-Doyle, 2017) where they position teachers as passive receivers of knowledge, giving them pre-made curricula and not allowing them to be agentic in this disruptive process (Adah-Miller et al., 2023). However, to shift in this way means that

professional learning settings must support teachers in developing their pedagogical judgment (Horn & Garner, 2022). This involves supporting not only their awareness of systemic injustice (Calabrese Barton & Tan, 2020) but also their abilities to explicitly attend to their students' and communities' cultural identities and histories (Penuel et al., 2022; Philip et al., 2019). Notably, this involves a professional learning setting designed to attend directly to teachers' sensemaking as they navigate this sociopolitical and pedagogical landscape.

This literature review has revealed the complex and diverse ways researchers have attended to and developed professional learning experiences to achieve these outcomes (Goode et al., 2021). In addition, it has shed light on the ways researchers have conceptualized and made salient what teachers' sensemaking looks like within moment-to-moment interactions (Horn & Garner, 2022; Philip, 2011; Scott & Louie, 2024). However, these same studies have also illuminated the limitations and implications for future research. The first is the need for more research analyzing the longitudinal progression of teachers' sensemaking (Daniel et al., 2023). Most existing studies capture short-term shifts (days or weeks) in discourse, noticing, and ideological shifts, but do not track how teachers sustain, refine, or abandon equity-focused approaches over months and years (Daniel et al., 2023; Kang & Zinger, 2019). While there have been select studies that have analyzed long-term sensemaking and the relational element among teachers (Penuel et al., 2012), they have explicitly stated the need for qualitative analysis, as their studies were quantitative. Future studies should also employ longitudinal methodologies, including ethnographic observations, repeated interviews, and case studies, to investigate how teachers' conceptualizations of equity might evolve over multiple years of PD engagement (Daniel et al., 2023; Kang & Zinger, 2019).

In addition, the social dimension of teacher sensemaking plays a crucial role in shaping teachers' engagement with equity and justice. Research has shown that teachers are more likely to embrace new pedagogical frameworks when they trust and respect their colleagues (Scott & Louie, 2024). However, the mechanisms through which teacher relationships influence sensemaking remain underexplored (Horn & Kane, 2015; Nasir & Cook, 2009; Penuel et al., 2022). Future research is suggested to explore how teachers' learning communities and relationships shape their willingness to adopt and sustain equity-focused ideologies and practices, and how power dynamics within these learning communities around equity discourses and implementation are shaped by teachers' prior relationships and professional expertise (Horn & Kane, 2015).

The need for continued research on teacher sensemaking of equity and justice is clear. Future studies must move beyond short-term assessments of PD effectiveness and explore how teachers sustain, modify, and institutionalize their equity-focused practices over time. Additionally, investigating the social and systemic factors that support or hinder these processes is essential for ensuring that these professional learning spaces contribute to individual teacher growth and collective enactment.

Chapter 3: Conceptual Framework

Introduction

The focal phenomenon of this study was a group of high school biology teachers who engaged in conversations over 2 years as they collectively designed an equity-centered unit, implemented it in their classrooms, and reflected on their experiences. In this study, the analysis focused on understanding the processes by which the teachers made meanings of equity-centered science instruction. The central aspect of this professional learning was engaging in the cycle of collaboratively designing an equity-centered unit, implementing it individually, and reflecting on the experiences together. Over the 2 years, the team was involved in this cycle twice. Grounded in sociocultural and sociopolitical perspectives on learning, I posited that this activity was nested in layered contexts (Scott & Louie, 2024). To examine teachers' collective sense-making processes over 2 years, I drew on pedagogical judgment (Horn & Garner, 2022) and cooperative action (Goodwin, 2017). As I unpack below, the pedagogical judgment framework helped explain how the teachers, as a collective, made a particular pedagogical decision at a moment. Goodwin's (2017) conception of cooperative action helped clarify how and why pedagogical approaches were modified over the 2 years.

Defining Pedagogical Judgment: Action, Reasoning, and Responsibility

Teachers' pedagogical judgment framework (Horn & Garner, 2022) illustrates the complex decision-making processes that occur both within and outside of the classroom, shaping teachers' instructional and relational interactions with students. This framework explains how and why a teacher engages in particular pedagogical activities and has three interrelated dimensions: (1) *pedagogical action*, or what teachers do; (2) *pedagogical reasoning*, or the rationale behind their actions; and (3) *pedagogical responsibility*, or the institutional, legal, and

moral commitments. Here, pedagogical actions refer to “the intentional and unintentional choices teachers make, both during and outside of the classroom instruction” (Horn & Garner, 2022, p. 59). Examples include teachers administering tests in their classrooms, deciding whether to allow students to use the bathroom, or collaborating with colleagues. All of these are teachers’ choices, which subsequently impact their classroom. In the context of this study, pedagogical actions encompassed three main components of the co-design unit: (1) essential question/gapless explanation, or guiding question and a storyline for the unit; (2) a capstone project and unit assessment, or evaluative and student-driven measures; and (3) activities encompassing the scope and sequence of the unit. Each of these actions illustrated the components of planning that guided the sensemaking conversations.

Teachers’ pedagogical actions, both inside and outside of their classrooms, are guided by their pedagogical reasoning. This involves the decision-making processes undergirding their actions. An example that Horn and Garner (2022) used is that “teachers may give tests because they want to see what students know; they may be following departmental policies to test weekly; or their action may be rooted in both reasons” (p. 59). In the two examples, while the teachers’ pedagogical actions may be similar, the rationale informing their decision-making processes may be directed towards different ends, whether to assess students’ understanding of content knowledge or to adhere to departmental policies. In the present study, all teachers on the co-design team agreed to participate in the capstone project, illustrating a shared collective pedagogical action. However, during the first year of the project, when the team initially developed the capstone design, some of the teachers’ rationales for implementing the capstone were to engage students with community members, while another teacher’s rationale was to focus on individual students’ awareness and accountability towards anthropogenically induced

climate change. As a result, while the teachers implemented the capstone project, the student work varied due to a lack of alignment between the reasoning and the action.

Informing this pedagogical reasoning was the idealization of the teachers' individualized notions of what constituted good teaching and pedagogical responsibility. Horn and Garner (2022) defined this responsibility as their "overarching commitments; these serve as both guides and anchors for pedagogical actions" (p. 59) and reasoning. These responsibilities emerged overtly when discussing what constituted good teaching or more subtly when the teachers explained their reasoning for specific pedagogical actions. Using the example above, one of the teachers who rationalized that the capstone project was meant to engage students with community members defined good teaching as classrooms being spaces where relationships between learning and the community exist. The teacher who explained the rationale for individual student accountability emphasized the importance of students developing skills related to becoming scientists. These commitments were rooted in how the individual teachers defined good teaching, were central to their identities, and stemmed from their personal and social backgrounds. Teachers' pedagogical responsibility directly reflected the ideologies they drew on when making pedagogical decisions inside and outside of their classrooms (Horn & Garner, 2022).

The Relationship Between Ideologies and Pedagogical Judgment

Critical to understanding the sensemaking processes teachers collectively engage in when making pedagogical decisions is the ideologies they draw upon in these moment-to-moment interactions. Here, ideologies refer to the mental frameworks that groups of individuals, or in this case teachers, draw upon to make sense of their social world and their in-class and out-of-classroom decisions (Hall, 1996). These ideologies are rooted within two forms of knowledge.

The first is *commonsense knowledge*, or information stemming from social interactions within informal settings that “stabilizes a particular form of power and domination” (Hall, 1996, p. 27), challenges the status quo, and is referred to as *naturalized axioms* (Philip, 2011). Drawing on discursive conversations in this study, a naturalized axiom was identified as any instance in which teachers’ language emerged from thinking rooted in White Eurocentric science education. For example, during a whole group conversation during an earlier PD in the first year of the partnership project, a teacher, not in the Living Earth team, explained, “I find that when kids care about something, it is usually because there is an adult behind them who cares about it, too.” Within the dominant culture of teaching (Lambert, 2015), a traditional view is that students are receivers of knowledge and the teacher governs the direction of learning. In this instance, we see that a naturalized axiom emerges in a teacher’s discursive language.

The second form of knowledge that teachers draw upon is *expertise-based knowledge*, which is acquired from prior professional learning experiences (diSessa & Sherin, 1996; Munson & Dyer, 2020; Odden & Russ, 2019; Philip, 2011). Like naturalized axioms, this form of knowledge can perpetuate or disrupt dominant ideological understandings. In this study, such prior experiences were identified during instances in which teachers directly referenced past professional learning experiences that guided their rationale. For example, Patty wanted to explain her rationale for the scope and sequence of the unit and drew upon her own, James’s, and Nina’s experiences conducting youth participatory action research (YPAR) during a summer program. Informing these teachers’ pedagogical reasoning was a responsibility stemming from their previous YPAR work.

Both of these forms of knowledge work in tandem. During the early stages of sensemaking, when individuals lack extensive, expertise-based knowledge, they primarily draw

on what they consider common sense. As their expertise-based knowledge grows, it becomes the primary driver for sensemaking, while commonsense knowledge is backgrounded (diSessa & Sherin, 1998; Philip, 2011). However, this shift is not linear or clean; it is often messy, with individuals frequently contradicting themselves within a single discursive conversation without recognizing the contradiction (Philip, 2011). This messiness between action and motive is encapsulated within the pedagogical judgment framework.

The Messiness of Sharing Pedagogical Judgment

In this framework, pedagogical action refers to what we observe teachers doing, physically inside and outside their classrooms, and is narrativized by their pedagogical reasoning. The reasoning behind their actions is rationalized by what they consider good teaching or their pedagogical responsibility (Horn & Garner, 2022). Like ideologies, pedagogical action and responsibility are not always aligned and, in many cases, can conflict (Horn & Garner, 2022). For example, Horn and Garner (2022) highlighted the pedagogical action of teachers assigning homework; however, when asked about the reason behind this decision, the teachers' answers were often tacit (Horn, 2005; Horn & Kane, 2015, 2019, 2022), stemming from a commonsense ideology that homework is just part of schooling. While a teacher can provide a reason for this decision, their responsibility may not stem from their motive but rather from the educational system they have been enculturated into throughout their lives (Hall, 1996; Horn & Garner, 2022; Philip, 2011). Critically, when teachers decide to challenge deeply-rooted traditional ideologies in schooling and enact non-traditional or disruptive pedagogical actions, it is here that sensemaking plays a crucial role in the ensuing decision-making processes (Horn & Garner, 2022).

Horn and Garner (2022) used the example of Mr. Green to illustrate how a teacher's pedagogical judgment can evolve as Mr. Green attempted to make sense of alternatives to homework. This is because Mr. Green, who always assigned students nightly homework and who was committed to good teaching, regularly assigned homework to prepare students for life but had noticed that many students were not turning in their assignments. As a result, many students' grades were beginning to suffer, and they were becoming less engaged in class. At this point, he wondered if changing his pedagogical action of giving homework daily was necessary to support his students. Horn and Garner (2022) provided three sample approaches for Mr. Green to revise his pedagogical action; two involve collaboration with his colleagues. Using the third approach in this example, Mr. Green worked alongside Ms. Ivory, who did not give homework because, in her view of good teaching and pedagogical responsibility, where she was committed to creating equitable spaces for all students, homework did not align with this goal. She explained to Mr. Green that she had had similar issues years ago and had found that most students who completed homework had access to resources, such as tutors, which directly conflicted with her commitment. Her pedagogical action directly conflicted with her responsibility, leading Ms. Ivory to adjust her pedagogical approach to align with her commitment.

Ms. Ivory's communication and transparency regarding past conflicts between her pedagogical responsibilities, reasoning, and actions may have influenced Mr. Green's pedagogical judgment regarding his homework issues. If Mr. Green aligned his pedagogical actions with Ms. Ivory's, this would indicate a re-articulation of his vision of good teaching and, subsequently, a change in his pedagogical responsibility and reasoning (Horn & Garner, 2022). An important note before proceeding is that the evolution of Mr. Green's pedagogical judgment

was not instantaneous; instead, it could potentially occur over a short to long period. For this reason, we have drawn on Goodwin's (2018) cooperative action framework, which illustrates how individuals participating in discursive conversations build upon language presented to construct meaning collectively. For example, Goodwin (2018) described a cooperative discussion between two boys that yielded a collective action:

Tony: [Why don't you] [get out of my yard]

Chopper: [Why don't you] make me [get out of the yard]. (p. 3)

Here, Tony actively attempted to get Chopper out of "his" yard while Chopper tries to stay in "the" yard. Chopper drew on Tony's language of "my yard," stating "the yard" to enforce Tony's lack of ownership and potentially substantiate his claim for being there, as it is "the" yard and not Tony's. Chopper's subsequent use of "the yard" instead of "Tony's yard" was context-driven language used to refute Tony's possessive claim. Without Tony's use of "my," Chopper's subsequent language usage would have varied. Given the context, the terminology of the "yard" represents the physical space that Tony was asserting possession of, to which Chopper attempted to refute. The "yard" in this discussion can be viewed as an artifact or semiotic resource that gives meaning to the boys' possessive language. As Goodwin (2018) explains, semiotic resources are the tools, actions, materials, and artifacts that language draws upon to make meaning. Tony's possessive use of "my yard" iterated his ownership and perceived power in removing Chopper from that space. Notably, the linguistic power of "my yard" stemmed from its connection to the physical space as a semiotic resource.

Similarly, when applying the idea of semiotic resources within the cooperative action framework (Goodwin, 2018) to the pedagogical judgment framework (Horn & Garner, 2022), pedagogical decision-making language directly represents the moment-to-moment actions

teachers take. Returning to the example of Mr. Green and Ms. Ivory, when Ms. Ivory explained the rationale behind her revised grading process, the language she used painted a picture of the actions, materials, and artifacts she used to assess students' understanding. Her language extended far beyond mere description of abstract thought; it became a direct representation of the pedagogical actions she employed in her classroom. As colors hold intrinsic meaning through the physical depictions they represent, so too does the language Ms. Ivory uses to describe the physical actions she employs every day to assess students. It is for this reason that, when I use the term 'semiotic resources' in the context of pedagogical judgment, I refer to the physical expressions of pedagogical actions and activities that teachers utilize in their classrooms every single day.

In addition to the use of semiotic resources within the context of pedagogical judgment, understanding the compounding nature of these transformative events is critical to ascertaining how teachers' decision-making language changes over time through numerous sensemaking conversations. To understand the scope of Mr. Green's shift, if he were to change his pedagogical actions, it would be critical to analyze the discursive conversation between the two teachers, especially regarding Mr. Green, to determine whether he drew on Ms. Ivory's linguistic features to rearticulate his pedagogical action and reasoning. This would illustrate how prior teacher interactions acted as potentially transformative events that may have shaped whether Mr. Green continued to assign homework.

Tracing the Evolution of Pedagogical Judgment Over Time: Substrates

Goodwin (2018) defined these transformative events as *substrates*, which are “both the sedimented outcome of earlier action, and the source of subsequent action” (p. 32). For Mr. Green, Ms. Ivory's explanation of her pedagogical responsibility and subsequent shift in her

pedagogical actions to align with her responsibility could be a subtle event. If Mr. Green were to change his pedagogical action later, not giving homework daily, then Ms. Ivory's prior conversations could be considered transformative because they were a source of change (Goodwin, 2018; Horn & Garner, 2022). Daniel and colleagues (2023) further elaborated on this framework of cooperative action by analyzing teachers' ideological rearticulation across multiple interactions over time within the context of teacher PD. Through analyzing and tracing teachers' discursive conversations over time, Daniel and colleagues (2023) demonstrated how teachers successfully engaged in the disruptive work of redesigning science instruction. Notably, teachers could not "fully articulate a coherent counter to dominant ideologies" (Daniel et al., 2023, p. 610). While the teachers were able to engage in the disruption and redesign of science instruction, they were unable to counter the dominant ideologies within science education fully. In addition, Daniel et al.'s (2023) analysis revealed that these shifts resulted from multiple interactions over time that built on one another to form collective shifts. The authors acknowledged a limitation in that this analysis focused on interactions over a short period (days), and called for further sense-making analysis over more extended periods (months to years).

To analyze long-term teacher sensemaking, Penuel and colleagues (2012) conducted a multi-year quantitative study using social network analysis to explore the impacts of PD activities and teachers' social influence on their individual and collective learning. The researchers concluded that while organized PD directly impacts teacher practice, so does teachers' exposure to "colleagues' prior professional development [which has] an indirect impact on their instructional practice" (Penuel et al., 2012, p. 128), highlighting the critical role of teacher interactions within these professional learning spaces. Scott and Louie (2024) elaborated on the socially contextualized nature of teacher sensemaking in their nested layered activity

model. In this model, they determined how moment-to-moment interactions are mediated by the localized context and culturally dominant system. The authors used the term *local arrangement* to refer to the localized context, defined as the activities, organizations, resources, and people (Horn, 2007), that comprise these spaces.

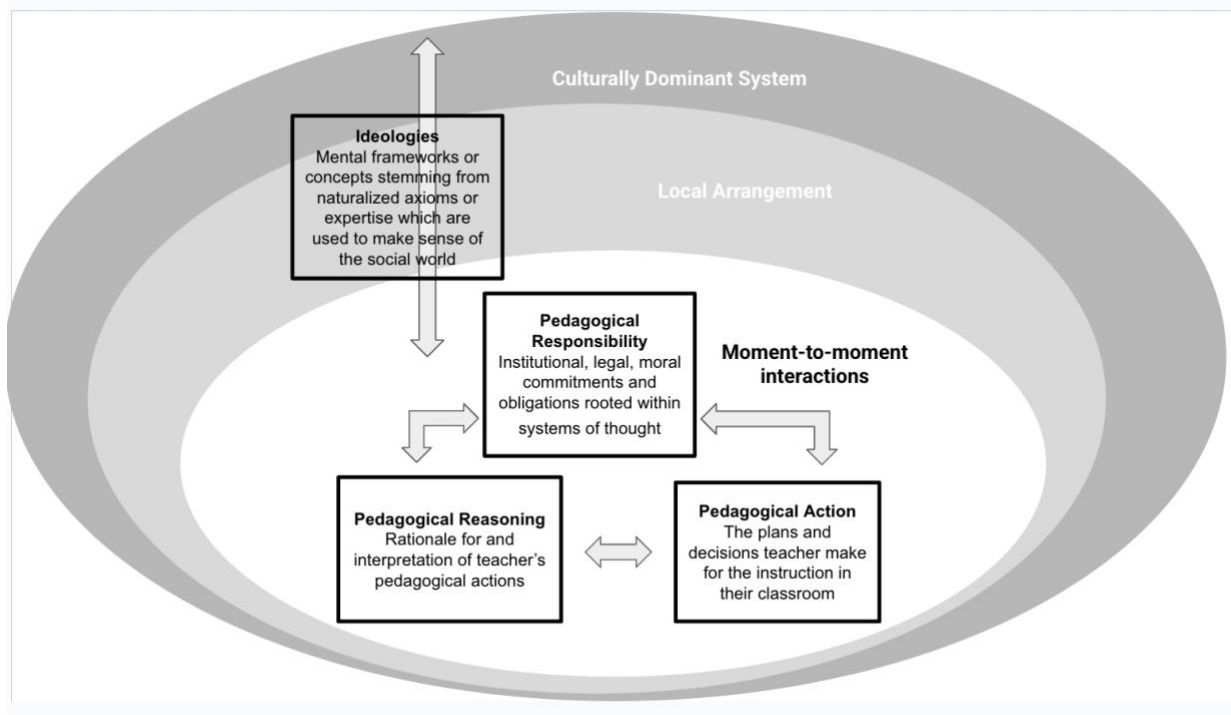
For the present study, I explicitly defined the local arrangement as the 2-year PD partnership project (localized context) within the local school district. Here, the activities referred to the mediating factors guiding teacher conversations, such as watching a video of good teaching and reflecting. Organization and resources referred to the tools, artifacts, and materials used in the PD to support teacher sensemaking during their equitable and just unit co-design. People referred to the relational interactions among teachers, facilitators, and district administrators that shaped collective sensemaking during the co-design process. All of these components comprised the local arrangement within the context of this study, as, according to Scott and Louie's (2024) definition, local arrangement is not a static structure but rather somewhat dependent on a study's design.

Importantly, equitable and just teacher sensemaking during moment-to-moment interactions, embedded within the local arrangement, either perpetuates or disrupts ideologies rooted in the culturally dominant system (diSessa & Sherin, 1998; Philip, 2011; Scott & Louie, 2024). From this perspective, I defined the culturally dominant system as White Eurocentric STEM education (Kang & Zinger, 2019; Scott & Louie, 2024), with the local arrangement serving as an equitable and justice-focused professional learning space for teachers. In this way, tensions might emerge between the ideologies stemming from the local arrangement and the culturally dominant system (Engestrom & Sannino, 2021). Moment-to-moment interactions then become windows into the observable manifestations of these inherent tensions that the group

navigates as it co-develops its equity-centered unit. Importantly, it is within these sensemaking conversations that teachers may either perpetuate, disrupt, or combine traditional STEM education with equity and justice (Bancroft & Nyirenda, 2016; Bang & Vossoughi, 2016). Using both nested layers of activity (Scott & Louie, 2024) and pedagogical judgment (Horn & Garner, 2022), I expanded on these ideas to develop the nested pedagogical judgment model (Figure 2).

Figure 2

Nested Pedagogical Judgment Model



I developed this model to illustrate the complex, context-dependent sensemaking processes that the teachers collectively engaged in to co-design their equity-centered unit (pedagogical action). Within any moment-to-moment interaction, the team engaged in sensemaking conversations shaped by the activities and structures within the PD (local arrangement) and the language used by facilitators to draw teachers' attention to specific aspects of equity during their planning time. They constantly navigated competing and aligned

pedagogical reasonings and responsibilities (Horn & Garner, 2022), giving merit and power to rationales and practices that aligned with their responsibilities at a given moment. Examining these nested moment-to-moment interactions over time enabled me to situate the team's collective reasoning and responsibilities within a given moment, rather than viewing them holistically at the beginning and end of the learning experience. Shifting practice for teachers is not simply about changing their pedagogical actions but about redefining their pedagogical responsibility and reasoning that informs the change in practice.

The interaction between teachers' action, reasoning, and responsibility played out through their discursive conversations, with a higher frequency when the pedagogical action was non-traditionally rooted or equity-based (Horn & Garner, 2022). These sensemaking conversations involved teachers collectively negotiating their reasoning for enacting pedagogical actions. These motives, for their reasons, were rooted in their pedagogical responsibility. However, that responsibility was not solely individual, especially given the context of the PD. Furthermore, I postulated that, through this nested pedagogical judgment model, teachers' collective sensemaking drew on common-sense knowledge and was rooted in Eurocentric STEM education. Simultaneously, the teachers were participating in a PD that actively supported their learning of equity, which directly conflicted with the ideologies of Eurocentrism (Engestrom & Sannino, 2021). As such, teachers were taking on responsibilities rooted in ideologies of equity and Eurocentrism. During these moment-to-moment interactions, I observed the navigation of these manifestations of conflict, evident in their discursive conversations about pedagogical action and reasoning.

One element of this model that was not illustrated was the temporal context of these events, given its two-dimensional nature. Returning to Goodwin's (2018) cooperative action

framework, the nested pedagogical judgment above highlighted specific moments, but when we compound multiple events on top of each other, they form a cylindrical model (in the z-axis) which illustrates how prior events can emerge as transformative for all subsequent events based on the emergent pedagogical reasonings and responsibilities. Using this model enabled me to analyze the emergence of the team's collective pedagogical judgment and its evolution over time in relation to the context (Scott & Louie, 2024).

Chapter 4: Methods

Study Context: A Partnership Between a University and Apple County School District in 2022–2024

This study emerged from a 2-year partnership project with a local school district focused on supporting teachers' learning in equity, justice, and civic engagement in the science classroom. The partnership work began in the fall of 2022 and continued until the end of the 2023–2024 school year. This school district, located in Southern California, comprised over 20 middle and high schools and served a student population of approximately 29,000. Within this district, 74% of students had been identified as economically disadvantaged, with approximately 25% of the student population qualifying for free or reduced lunch. The racial demographic of the district were: 70% Latinx, 17% Asian or Asian Pacific Islander, 8% White, 2% Black or African American, 2% identified as more than one race, 0.5% Native Hawaiian or Pacific Islander, and 0.2% American Indian or Alaska Native (U.S. News, 2022).

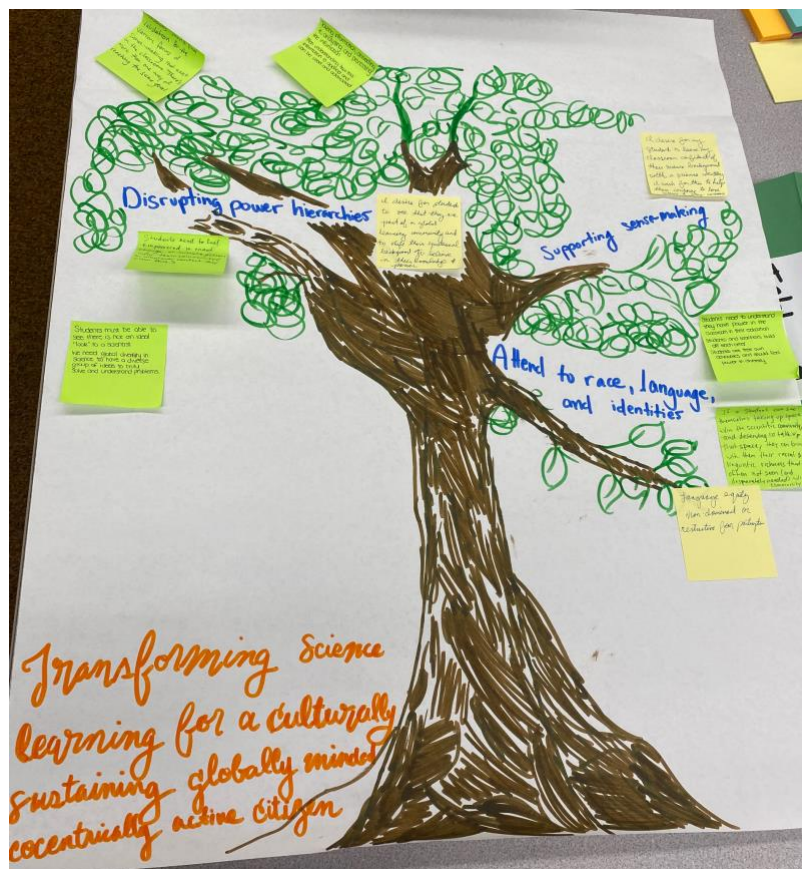
Within this partnership project, teachers collaborated with researchers, educational leaders, community members, and scientists to co-design civic engagement and climate-centered units. Year-long professional learning activities, collectively designed by the researchers and teacher leaders of the school district, aimed to support teachers' understanding of equity, justice, and civic engagement within the work of science teaching and learning at schools. The main activities included: experiencing a researcher-designed model unit; discussing a range of conceptions of equity and justice; co-designing justice-centered curricula and assessments that promoted students' civic engagement; enacting the curricula and assessments in classrooms, analyzing the students' work; and reflecting on the enactment. These learning experiences were designed to support the participating teachers in developing and aligning the elements of their co-designed units to contemporary understandings of equity, justice, and civic engagement. More

specifically, the modeling of the justice-centered science unit took place during the first PD session at the start of both the first and second years of the partnership. Teachers took on the role of students, and the lead researcher/facilitator assumed the role of the teacher. Here, the facilitator guided the teachers through critical, justice-centered science activities spanning a unit on food waste and food insecurity. The teachers engaged in activities as students, attending to a social justice science issue (Morales Doyle, 2017) and sharing and contributing knowledge stemming from their personal and cultural backgrounds; in this way, they were positioned as epistemological agents within science. In both years, the PD began with engaging teachers in a researcher-developed unit as learners. The model unit served as a subject of collective inquiry, a shared experience that the team could refer back to, while presenting one possible image of justice-centered science instruction.

Subsequent PD focused on emerging and norming the ideologies and definitions of equity, justice, and civic engagement that teachers understood before co-designing their units. This involved teams developing a shared understanding of the terms (ex. equity, justice, equality, etc.) along with developing artifacts that outlined their collective commitments (Figure 3). Figure 3 shows one artifact, a commitment tree, produced from this activity. The branches represented the chosen principles, with sticky notes connotating their inputs, and the base of the tree demonstrated the unit's culminating commitment to equity.

Figure 3

The Living Earth Team's Co-Constructed Equity Tree



After teams had made nascent their equity commitments for the unit, they began developing the capstone-worthy project (the final project) and the assessments (pre- and post-tests). The unit's planning follows a backward planning approach, with assessments developed first and activities planned around them. For both the first and second years, the overall structure remained consistent, with more time devoted in the second year to having teachers reflect on the holistic data collected and analyzed over the summer by the teacher researchers. Notably, one member of the Living Earth team, Patty, participated in the summer teacher–researcher program (a point discussed in greater detail in the Findings section). As a teacher–researcher, she analyzed student

assessment data, including artifacts from the capstone-worthy projects, collected from all Living Earth team teachers in collaboration with the researchers.

Throughout each year, the teachers worked within content-based co-design teams to design and enact a justice-centered unit that addressed the Next Generation Science Standards and promoted students’ civic engagement. They met either in-person or virtually approximately once per month. During the fall and winter quarters, teachers engaged in co-design activities. Then, during the spring quarters of the 2022–2023 and 2023–2024 school years, they implemented these 4–6-week co-designed units in their classrooms, during which time the research team recorded weekly lessons for the designated focal teachers. The timeline for the PD and enactment of the co-design units is represented in Table 1.

Table 1

Two-Year Partnership Timeline for the Southern California School District

Year	Quarter	PD schedule	Phase
Year 1 of the partnership	Fall 2022	October: PD#1 December: PD#2	Develop a shared commitment
	Winter 2023	January: PD#3 February: PD#4 March: PD#5	Co-design: Assessments & activities
	Spring 2023	May: PD#6	Enactment (I) & reflection
	Summer 2023	N/A	Data analysis
Year 2 of the partnership	Fall 2023	August: PD#1 September: PD#2 October: PD#3	Revision of capstone
	Winter 2024	January: PD#4 February: PD#5	Revision of assessment & activities
	Spring 2024	May: PD#6	Enactment (II) & reflection

Pedagogical Context: Overview of the Living Earth Co-Designed Unit

In the first year of the partnership, the Living Earth team developed its co-design unit around this essential question: “How have the various histories of use of our land contributed to the changing climate of Apple County?” The teachers outlined four primary outcomes and goals for students through their participation in this unit: (1) understanding and communicating the stories of historical land use, (2) developing and using models to illustrate how land use has impacted biodiversity, (3) constructing evidence-based arguments detailing the intersection between historic and current land use and climate change in regards to temperature and precipitation changes, and (4) designing and evaluating a proposed solution to reduce the impact of anthropological activities on the environment and biodiversity.

To do this, the co-design team first structured the unit to present historical images and photos of Apple County. Students would then be invited to share stories about their ancestors and the people who lived on this land, and how the land and its usage had changed over time. Utilizing an initial assessment focused on historic and current land use, the teachers gathered data on students’ prior knowledge. In the following weeks, students engaged with texts and readings focused on the current and historic land use of the local indigenous tribes. Here, they drew comparisons between the land use of indigenous and dominant cultures, engaging in scientific activities focused on the carbon cycle and on current land use practices that contribute to changes in temperature and precipitation patterns. This culminated in activities in which students conducted a “community walk” to analyze native and invasive flora and fauna in their communities. Using this data, they developed a presentation, dubbed the “capstone,” which they presented to their class, and engaged in the final assessment task that invited students to use their knowledge of climate change and land use to predict the future.

In the second year of the partnership work, the Living Earth team added two new members and refined their essential question to: “How can we, as stewards of environmental justice, acknowledge the actions of the past to mitigate human impact on climate change for more sustainable Earth ecosystems?” A prominent change in the co-design unit was moving away from focusing on climate change (temperature and precipitation), as these topics were too abstract when considering changes in the historical use of local land. Instead, the team decided to focus on anthropogenic activities that impacted local biodiversity, linking how changes in biodiversity shape environmental conditions. While many parts of the unit were under revision at the time of this study, the team stated on numerous occasions that the first few weeks, which focused on the historical use of land by the local indigenous tribes, would remain unchanged. This element of the co-design unit highlighted the historical oppressions faced by the local indigenous community, and the team acknowledged that it was critical to the unit. A significant shift in the unit involved moving the “community walk” to the beginning, thereby creating a greater focus on localized biodiversity issues.

Furthermore, the teachers highlighted that while the community walk was an impactful activity from the previous year, students needed more support and modeling before conducting it in their local community. As such, the teachers created a modeling activity dubbed the “campus walk,” in which they could scaffold students’ problem identification and analysis of invasive and native flora and fauna. This aimed to make the community walks more intentional and focused on collecting relevant data to understand biodiversity.

Another change the co-design team made was to shift the capstone’s focus away from being completely solution-oriented. Teachers discussed how the capstone’s solution-oriented focus limited how students could engage with the issues they identified during their community

walks. For instance, Patty, one of the returning members from the previous year, highlighted a desire for student capstones to raise awareness of biodiversity issues caused by invasive species. She noted that some students wanted to emphasize the problems posed by non-native and invasive plant species, which require more water than native species, thereby contributing to the community's water problems. Here, the students' focus was not on solving the problem, but on raising community awareness of the issue. The co-design team sought to expand the scope of what students could present in their capstone projects. The emphasis was on allowing students to address issues through an awareness of community voices or problems, or by proposing potential solutions to issues they encountered during their community walk.

Participating Teachers

In Year 1 the Living Earth team consisted of Patty, James, Nina, and Samantha. Patty was a Latina female who spoke both Spanish and English fluently. She had 15+ years of teaching experience within the district and currently taught 9th-grade biology, with some of her classes serving high percentages of multilingual (ML) students. In addition, Patty had worked on numerous initiatives within the district, collaborating with both Nina and James, particularly with Nina, with whom she had a long-standing professional relationship.

James was a Latinx male fluent in Spanish and English, with over 4 years of teaching experience. James taught designated dual-immersion biology classes, in which instruction and discourse used both Spanish and English. James and Patty had both received training in translanguaging practices from the district. James, Nina, and Patty had also taught in a summer language program to support students who had recently migrated to the country and were learning English as a second language.

Nina was a White female who spoke only English and had 20+ years of teaching experience. She currently taught general education biology classes, with a small percentage of her classes having designated ML students.

Samantha was a White female who spoke only English and had been teaching for 9 years. Like Nina, she taught a general education biology class, with a small percentage of her class being designated as ML students.

Then, in the second year of the partnership project, two new teachers were added to the team, Rob and Elisa. Rob was a White male with 20+ years of teaching experience and worked in a district with a more economically affluent area. The team was aware of the differences in the economic statuses of different schools within the district. Lastly, Elisa was a Latina female in her 7th year of teaching and was fluent in English and Spanish. Towards the middle of the second year of the partnership project, Patty transitioned into a different role within the district, and Elisa assumed the teacher position in her school.

Data Generation

Data for this study were generated from three primary sources within the 2-year partnership project: (1) video-recorded professional learning experiences involving both whole and small group sensemaking conversations, (2) video-recorded interviews with individual teachers, and (3) teacher-developed pedagogical plans and activities for the co-design unit. Over the course of the 2-year partnership, a total of 12 PDs were video-recorded (six separate PDs in both Years 1 and 2). During each of these PDs, two video cameras were used to capture video and audio data on facilitator-led learning experiences, along with the sensemaking conversations the teachers engaged in afterward. Here, the first camera provided contextual information on the language the facilitator used to frame different learning experiences, while also capturing whole-

group discussions among teachers about their reflections on these experiences. The second camera and microphone were focused on a designated team to capture the subsequent sensemaking conversations that a team of teachers engaged in during these learning experiences. Together, the combined camera footage from the PD sessions provided a comprehensive analysis of the contextual learning experiences and subsequent conversations a team of teachers engaged in afterwards. Notably, this was done for each of the 12 PD sessions over the 2 years.

The second set of data consisted of video-recorded semistructured individual interviews with participating teachers over the 2 years. These interviews focused on ascertaining teachers' perceptions of their own pedagogical practices, their conceptual understanding of equity, justice, and civic engagement, and reflections on elements of the PD that shaped their learning. To monitor teachers' perceptions, interviews were conducted at four points: (1) at the start of the first year (all participating teachers), (2) at the end of first year (focal teachers only), (3) at the start of the second year (focal teachers only), and (4) at the end of the second year (all participating teachers). Initial/final project interviews provided holistic data on the perceptions and understanding of all participating teachers. In contrast, the more frequent focal-teacher interviews provided an in-depth look at step-by-step shifts in pedagogical understanding.

The last form of data collected and analyzed in this study was the co-designed units developed by the Living Earth team. Over the 2 years, the Living Earth team created and shared their planned pedagogical activities, unit plans, and curricula in a cloud folder accessible to the team. These documents were organized and categorized into different folders to facilitate the later analysis of shifts in planned pedagogical actions between the first and second years of the partnership. This allowed for analysis of changes in the unit's design and potential connections

between these shifts and the sensemaking conversations that aligned with them. Table 2 shows the various data sources used in this study.

Table 2

Data Sources

	Data sources	Analytical processes
RQ1	Teacher-developed co-designed unit and lesson plans	Analyzed shifts in collective pedagogical action through a comparison of Year 1 and 2 teacher-developed artifacts
RQ2	- Co-design team meetings - Interviews with focal teachers	Using the pedagogical judgment framework (Horn & Garner, 2022), analyzed shifts in collective and individual pedagogical responsibility
RQ3	- Co-design team meetings - PD recorded whole group learning experiences	Compared interconnected events between the whole group and small group settings to contextualize shifts in language

Analytical Approach

To answer the three RQs, this study analyzed 5,718 minutes of video footage from the 2-year partnership project. This footage involved 3,702 minutes of whole-group PD and 2,016 minutes of small-group Living Earth co-design team meetings. In the whole-group PD setting, teachers engaged in PD activities (model lessons, presentations of student data, feedback on unit activities, etc.), whole-group reflective discussions on pedagogical enactment, and input from teachers/facilitators on the implementation and conceptualization of equity, justice, and civic engagement. On the other hand, the small group setting involved the Living Earth team's sensemaking conversations, where they collectively planned pedagogical actions for the co-design unit, analyzed student work samples to make revisions in the unit's design, and discussed and reflected on conceptualizations and pedagogical reasoning focused on equitable and just science

teaching presented in the whole group setting. The small group data consisted of 2,595 minutes of video footage from Year 1 and 3,123 minutes from Year 2.

Analysis of the video footage involved a holistic two-cycle coding approach, with a focus on understanding how the science team's pedagogical judgment had evolved. The first cycle involved reviewing all 5,718 minutes of video footage, identifying key events, and conducting a preliminary analysis of these events. During the review and identification process, I drew on Bannister's (2018) definition of sensemaking conversations, characterized as "the social, historical, and contextual nature of knowledge's co-construction" (p. 131), to define the scope of the sensemaking units. In addition, the NASEM reports (2022, 2024) provided language associated with equitable and just science teaching to identify emerging events that could illuminate potential shifts in thinking over time. Utilizing both of these conceptualizations, I drew up three criteria to use as a means to identify relevant events that provided insight into the collective ideological expansion: (1) when the context explicitly forced the teachers to talk about or define equity, justice, and civic engagement, (2) when the teachers talked about how to support historically marginalized students, and (3) when the teachers talked about why/how they should do these things, especially when they had a disagreement or tensions arise or confusion with enactment. Using this criterion, 63 events were identified across the 5,718 minutes of video footage, resulting in roughly 945 minutes of video footage being coded initially.

After the identification process, I used an open coding approach to determine whether and how the Living Earth team's conceptualization and understanding of equity, justice, and civic engagement had changed. I developed analytic memos for each of the 63 events, focusing on insights into the three criteria established earlier to deepen the understanding of how the science team's thinking had evolved over the 2 years. These analytic memos included transcripts

of the video footage, contextual details of the PD activities surrounding each event, summaries of the conversations that took place, and preliminary analyses of criteria #2 and #3. Once the analytic memos had been developed for all 63 events, I created a matrix to organize the progression of these events within their respective PD over the 2-year partnership project. This enabled the full contextualization of each event through subsequent analyses, eliminating the need for follow-up reviews of the PD context.

At the conclusion of the open coding process in the first coding cycle, the team's preliminary analyses illuminated general shifts in its conceptual understanding of equity, justice, and civic engagement. An example of these holistic shifts was an increased frequency, by all team members, of using language to address localized (neighborhood/community) problems that impacted biodiversity, in contrast to the first year, when competing ideologies emerged, with some members focusing on providing supports and scaffolds for multilingual learners. Others were focusing on indigenous history. Holistically, the team had become more focused while also demonstrating a more nuanced and advanced understanding of pedagogies for equitable and just science instruction (NASEM, 2024). However, these analytic memos provided limited insight into the progression of this language over time and the potential connection between whole-group and small-group settings. As such, the preliminary open-coding analysis revealed changes in the team's language that required further insight.

Shifting to the second coding cycle, the initial focus was to address RQ1 and RQ2, understanding how the team's pedagogical judgment had changed over the 2 years. I used an inductive coding process to determine the scope of the team's collective shifts in understanding equity, justice, and civic engagement within the context of the whole group PD setting. This coding process involved applying three frameworks outlined in the conceptual framework

section: pedagogical judgment (Horn & Garner, 2022), layered activities (Scott & Louie, 2024), and cooperative action (Daniel et al., 2023; Goodwin, 2017). Together, they enabled the linguistic dissection of the team's collective longitudinal thinking, contextualized within the PD setting. In the second cycle, events were initially coded using the pedagogical judgment framework, with each event coded according to the predominant pedagogical action that emerged. These events were then recategorized within the matrix, allowing me to analyze the specific changes in the team's planned pedagogical actions, along with the language changes associated with its pedagogical decision-making processes. The three categorizations for the planned pedagogical actions were: (1) unit outcomes and essential questions (n = 9), (2) assessment and capstone (n = 16), and (3) unit activities with the community walk (n = 15). Additionally, there were two other event categories (teachers' and facilitators' sharing of reasoning and responsibility), which provided contextualized information to ground the teachers' learning experiences (n = 23).

Simultaneously, I analyzed individual interviews with each Living Earth team member to gather information on changes in their pedagogical responsibilities from the start to the end of the partnership program. This entailed eight hours (four 1-hour interviews at the beginning and end of the partnership) during which I analyzed the teachers' definitions of "good teaching" and of social and racial justice. Using the teacher's pre- and post-individual interviews and the events categorized by the focal planned pedagogical actions, I conducted an analysis of changes in the unit's design and the ideologies that informed those decisions. Data from the interviews provided insights into the start and endpoint for each teacher's pedagogical responsibility, drawing on Horn and Garner's (2022) focus on good teaching, as well as on instances in which the team emphasized its commitment to equity, justice, and civic engagement. Analyzing the collective

responsibilities that emerged over the 2 years, along with the interviews, highlighted how the team's pedagogical responsibilities shifted from the beginning to the end of the program. The analysis will address RQ1 and RQ2 in Parts A and B of the Findings section.

For RQ3, to understand the potential connection between the linguistic shifts in the team's reasoning and the whole group setting, I used a combination of the pedagogical judgment (Horn & Garner, 2022), layered activities (Scott & Louie, 2024), and cooperative action (Daniel et al., 2023; Goodwin, 2017). Here, the collaborative action framework (Goodwin, 2017) attended to the transformation of language through its accumulation within specified contexts, which Goodwin (2017) referred to as *substrates*. Applying this conceptualization to the matrix and to the 63 events, I conducted an analysis to identify where, over the 2 years, the team's language changed most significantly. The results of this analysis revealed a time period between the team's initial enactment of their unit and 2–3 months into the second year of the partnership, during which dominant shifts in the language associated with the teachers' pedagogical judgment emerged. Subsequently, all events within these time periods were re-analyzed using the nested layers of activity model (Scott & Louie, 2024) to determine whether any connections emerged between the language of the whole-group setting and the science team.

Following the Living Earth team's initial enactment of their co-design unit, a total of 47 events emerged in the PD context in which the teachers or facilitators explicitly addressed the constructs of equity, justice, and civic engagement. Among these 43 events, 24 emerged within the temporal period between the first and second years of the partnership project, during which notable shifts in language were identified. By isolating these 24, 5- to 8-minute discursive events, encompassing both whole-group and small-group conversations, I analyzed the shifts in language within and across settings. Utilizing the three frameworks, I developed four questions

to guide the analysis of this data and address RQ#3: (1) What language used within the whole group PD setting was drawn upon (taken up/appropriate) by the Living Earth team during their co-design conversations? (2) What components of the Living Earth team's pedagogical reasoning language disappeared, emerged, and shifted post-enactment? (3) How did language associated with pedagogical reasoning change over time within the whole group setting? and (4) How did the shifts in language of the whole group setting potentially shape those of the Living Earth team?

I reanalyzed the previously developed analytic memos using the four guiding questions to identify potential relationships between the language used in whole-group and small-group settings. In addition, I developed a second coding matrix (an example is shown in Appendix A) for this transformative linguistic period, in which I re-coded pedagogical actions, reasoning, and responsibilities to identify potential relationships between the pedagogical judgments of both settings. During this transformative period, I re-coded the emergent pedagogical actions, reasonings, and relationships based on topic and frequency, and positioned them within the matrix to provide a holistic view of the data. I developed a total of 21 codes using an in-vivo methodological approach to analyze pedagogical actions, reasoning, and responsibilities in both whole-class and small-group settings. Whole- and small-group events were temporally positioned relative to one another within their respective PD settings. Through this process, I situated these events within their respective nested, layered systems, contextualizing both small- and whole-group conversations within the overall learning activities.

Opposed to the previous RQs, the focus of this analysis was not the progression of specific actions or responsibilities but rather the potential connection between these settings, in relation to the language associated with their pedagogical judgment. Across five PD days

(spanning five–six months), comprising nine whole-group and 15 small-group events, patterns emerged in the language used to describe the pedagogical actions, reasoning, and responsibilities of whole and small groups. These trends and patterns are discussed further in Part C of the Findings section, highlighting the potential relationship that emerged between the PD setting and the small group’s shift in understanding of equity, justice, and civic engagement.

Chapter 5: Findings

Introduction

The study findings are presented in three sections, Parts A to C, which address the three RQs. Part A describes the overall changes in the co-designed unit's features over the 2 years. Specifically, I compare key components of the unit design that shaped student experiences, highlighting the differences between the 2 years. Part B presents an analysis of the individual and collective professional discourses that reflected the team's understandings and commitments to equitable science instruction from the start to the end of the partnership. In addition, I highlight shifts of the languages in the collective sense-making conversations between the first and second years. Tracing the team's evolving sensemaking conversation helped me theorize how and why the team changed its practices. Lastly, in Part C, I analyze these shifts in relation to the semiotic resources presented during the professional learning activities. By tracing how the semiotic resources supplied by the researchers during the whole group conversation were taken up, appropriated, or expanded, I examine the potential relationship between professional learning experiences and shifts in the team's pedagogical judgment.

Part A: Overview of the Holistic Changes in Pedagogical Actions Between Years 1 and 2

Guided by the pedagogical judgment framework (Horn & Garner, 2022), I analyzed the collective evolution of teachers' pedagogical judgment, focusing on shifts in their action, reasoning, and responsibility. In this section, when I use the term *responsibility* I am referring to the ideologies and commitments that teachers hold as essential to good or equitable teaching (Horn & Garner, 2022). These responsibilities undergird the moment-to-moment decision-making processes teachers plan or employ daily. Horn and Garner (2022) referred to these decision-making processes as teachers' pedagogical reasoning. In the pedagogical judgment

model, actions are determined by a teacher's reasons, which are guided by what the teacher considers good teaching or their responsibilities at the moment. In the learning and sensemaking process, it is essential to distinguish between these constructs as shifts in practice highlight an ideological change within an individual's or collective's definition of good and just teaching (Horn & Garner, 2022).

Within the context of this study, the teachers' actions were manifested through the design of curriculum and assessment materials produced from the co-design activities. Notably, shifts in collective reasoning and responsibility occurred over multiple moment-to-moment interactions between teachers and facilitators, who were situated both internally (within the Living Earth team) and externally to the team. The scope of these combined shifts in pedagogical responsibility and reasoning over 2 years could be understood through the evolution of discursive conversations and changes in planned instructional activities within the co-design unit. To fully encapsulate these changes in collective pedagogical responsibility and reasoning, in Part A I first draw attention to the planned changes to the unit's design made by the Living Earth team between the first and second years of the partnership. In the following section I present the changes in teachers' discourses, reflecting the changes in their responsibilities and reasoning.

As part of the PD learning experiences, co-design teams were tasked with creating a unit driving question, a gapless explanation, a capstone project, initial and final assessments, and lesson activities throughout the process. The driving question and gapless explanation for the co-design unit acted as its foundation. Teams were tasked with designing these elements of their unit during the first few PD sessions, using a backward-planning process. During subsequent PDs, teams created assessments and capstone projects, with the unit activities being designed

last. This was intended to ensure that teams had clear goals for these activities, with the unit's purpose and expectations already having been established.

A key note is that the capstone project was an initiative pushed by the local school district and integrated into the unit design. The capstone project was being rolled out across all subjects, not just science, and focused on students addressing relevant civic issues in their communities and neighborhoods. As such, the capstone's language and expectations were promoted throughout these PD learning experiences and during the district's professional learning sessions. However, this partnership project was co-developed to align the planning and unit development processes with the district's initiative to support civic-centered capstone projects. In doing so, the participating teachers in this partnership project were further refining their understanding and planning processes by using pre-established structures. As such, the unit each team developed applied not only to their classrooms but also across the district, as it aligned with the district initiative. With that in mind, I begin this section by contextualizing the changes in the team's pedagogical judgment over the 2 years and analyzing shifts in unit features between the first and second years.

Holistic Changes in the Unit's Design Between Years 1 and 2

As mentioned, across the co-design units, teams were tasked with creating multiple documents for both teachers and students. It was within these teacher-developed documents that I synthesized key shifts that emerged between the first and second year. A summary of the changes to the unit's key features (driving question, initial/final assessments, capstone project, and community walk activities) is provided in Table 3. Additionally, these teacher-developed resources are included in Appendix A.

Table 3*Holistic Overview of Changes in the Living Earth Team's Co-Design Unit*

Unit's key features	Year 1 Equity and Justice Focus	Year 2 Equity and Justice Focus
Driving question	● Highlighted students' individual connections and stories' with the land around them ● Address climate change as a global issue	● Explicitly positioned students as agents of change ● Focus revolved around students being "stewards" of the land and maintaining biodiversity ● Foreground local Indigenous practices
Gapless explanation	● Focused on students' understanding of climate change ● Understanding the local history of the land around them and the ways it had changed post colonialization	● Shifted the purpose of the unit to raise students' awareness of local injustices and support them in developing sustainable actions for future generations
Unit Activities	● Standards mastery activities (ex. Carbon Cycle Game) were planned frequently throughout the unit's design ● Readings attended to local Indigenous history and "how they felt having their land taken from them?"	● Civic-centered activities (ex. campus/community walk) were foregrounded in the unit's design, with the campus walk initiating the unit enactment ● Campus/Community Walk - students walked around their campus/community and identified issues pertaining to biodiversity that were impacting their community
Capstone	● Project focused on students' individual connection with the land ● Students created power points/posters to present to their class on their observations ● Students discussed the general relationship between climate change and local biodiversity	● Project focused on students' awareness and action against local issues related to biodiversity ● Students' power points/posters were designed to be given to community members or policymakers to enact change ● Students focused on the relationship between locally identified issues and biodiversity

Change in Unit Design Pattern #1: Shift From Awareness to Action

Between the first and second years of the partnership project, the specificity and clarity of the unit's purpose and focus on equity, justice, and civic engagement became more evident. In the unit's driving question, which served as the guiding foundation for the unit's design, the team initially focused on the local impacts of climate change resulting from historical and current land-use practices. The initial driving question stated, "How have the various histories of land use contributed to the changing climate of Apple County?" The language highlighted the team's focus on analyzing climate change resulting from historical and current local land-use practices. Specifically, they utilized the targeted language of "various histories" to convey potential periods and historical events that contributed to it, as well as the direct impacts of land use on localized climate change.

In comparison, the driving question for Year 2 continued to focus on climate change, with numerous revisions to the language. The first revision included "stewards of environmental justice," with "stewards" emphasizing the individual's responsibility to act. In contrast to Year 1, the team explicitly used the language of "environmental justice" to indicate that students' stewardship focused on addressing injustices related to climate change. This was further expanded upon in the next part of the question, where the team targeted the past, present, and future history of injustice, with students needing to be able to "acknowledge the actions of the past to mitigate human impact on climate change." Notably, the team targeted students' awareness through the phrase "acknowledging actions of the past," which could be interpreted as recognizing the contributions and historic injustices that shaped or mitigated climate change. The driving question focused on students as stewards who would usher in a more sustainable

ecosystem: “How can we, as stewards of environmental justice, acknowledge the actions of the past to mitigate human impact on climate change for more sustainable Earth ecosystems?”

Fundamental to this shift was the use of the term “we” in the second year’s driving question. This language positioned students as agents of change, shifting their role from passive observers of injustice to active disruptors of it. The transition from awareness to action also emerged within the team’s gapless explanation and capstone project (which remained action-oriented, but more aligned with other features of the unit). Similar to the driving question, the gapless explanation was a planned design feature of the PD, with teams constructing a storyline that outlined the conceptual flow of their unit. In Year 1, the team’s gapless explanation focused on connecting the historical stories of students, families, and communities to land-use changes and aligning them with the Next Generation Science Standards. Here, the team stated that “students will be tasked with designing the proposed land use for a sustainable and thriving future,” an action-oriented unit focus. Compared to their driving question, which was awareness-focused, the unit’s initial focus in the first year was on competing with itself, which illustrated a lack of clarity.

Comparatively, in Year 2, the gapless explanation remained action-oriented, but the driving question was now aligned in focus. Furthermore, the specificity of the team’s language illustrated a targeted focus not only on raising students’ awareness of past and present injustices but also on leveraging the knowledge and experiences of historically marginalized communities to inform future sustainable actions. Similar to the driving question, the team’s language illustrated a unified and targeted approach toward addressing past, present, and future forms of environmental justice, as well as the role of Indigenous knowledge in informing that understanding.

This shift in focus, from awareness to action, emerged within the revisions made to key unit activities and the capstone (culminating) project. Here, the capstone project served as the unit's summative project, driving the unit's learning experiences and providing students with an opportunity to engage in equity, justice, and civic engagement. In the first year, the team designed the capstone project as a presentation or poster that students developed detailing their personal history with the land and how climate change has been affected by land-use changes. Importantly, from the student work samples collected from each teacher's capstone project, Patty, Nina, Samantha, and James all worked towards differing goals in the design of this project. For example, Patty and James emphasized students' observations of the community; Samantha focused more on global climate change; and Nina had students discuss predator-prey relationships in relation to biodiversity. The team's differing foci yielded capstone projects that collectively addressed students' relationships with the land, but in terms of equity, justice, and civic engagement, pursued different goals.

Comparatively, in the second year of the partnership project, the team developed the capstone project with the goal of having students engage with locally driven, relevant issues emerging in their community that impacted biodiversity. Specifically, the capstone project's goal moved beyond students' relationship with the land; instead, students identified issues that mattered to them and outlined actionable steps to address in their role as "stewards of the land," as stated by Rob and Patty. To do this, the team shifted the entire structure and timing of activities throughout the unit, foregrounding those that supported students' ability to become aware of and take action against localized injustices. They started the unit off with the campus and community walk, an activity that only a few of the teachers had implemented at the end of the unit during the previous year. Here, they would have students walk around the campus and

their community to identify man-made factors that shaped land use. The purpose of which was to explore the impacts on local biodiversity. Students would then use these observations to develop a “Call to Action” in the form of a letter, presentation, and poster, which they would use to inform their community members or notify policymakers of these issues.

Fundamentally, while the activities within the unit were moved around, the inclusion of the campus and community walk at the beginning of the unit grounded students’ inquiry in locally driven issues. This shift in focus moved the unit's previous goals away from centralizing standards-based mastery activities toward civic-centered goals designed to support the development of their awareness and action against localized injustices. Through their capstone project, they developed strategies to engage community members and potentially communicate with policymakers. These changes positioned students as change agents, working from a stance of civic engagement and actively seeking to improve their own communities.

Change in Unit Design Pattern #2: Increased Clarity of Expectations for Students

While the unit’s action-focused nature was originally the capstone project’s purpose and design, the clarity and explicitness of the approach evolved between the first and second years. In the first year of the partnership, the team referred to the capstone project as a “call to action,” designed to encourage students to engage with community members on climate change issues. Initially, the team developed five distinct modalities for students to engage with the capstone project, each involving different activities and using data from their respective communities (see Appendix A). However, unlike the second year, no supports, scaffolds, or rubrics were provided (from the submitted resources) to assist students in articulating what addressing injustice through these modalities could look like in practice. This was much different in Year 2, where the

explicitness of the expectations, as well as the targeted supports and scaffolds, were planned features within the unit's design.

Although the overall purpose of the capstone project remained unchanged between the first and second year, the team expanded upon their initial design to develop clearer expectations and targeted supports, aiming to enhance students' awareness of injustices within their local communities. In doing so, students could articulate more focused actions that addressed these localized injustices. To achieve this, the team built on the community walk from the previous year, which was initially scheduled for the end of the unit, preceding the capstone, and added the campus walk. The inclusion of this activity was designed to provide students with opportunities at the beginning of the unit to develop their awareness of localized injustices related to declining biodiversity. Along with the project document, teachers also provided students with a rubric that differentiated between awareness and action, illustrating students' proficiency levels in their work. The team conceptualized social justice within five components: (1) historical community connection, (2) framing the problem/concern, (3) critical awareness of injustice, (4) nature of the proposed solution, and (5) voices and experiences. These conceptualizations stemmed from Patty's work as a teacher-researcher over the summer between Years 1 and 2 of the partnership.

The team's increased levels of specificity and action-oriented focus were a direct product of the evolution of their pedagogical judgment. Although visible shifts emerged within the team's planned pedagogical actions, these changes indicated a shift in what the team considered equitable and just teaching. Additionally, their ability to explicitly attend to targeted historical and present injustices highlighted a conceptual change in their awareness and understanding of what it meant for students to engage successfully with localized issues. Importantly, this also highlighted a team that was potentially more aligned in the second year, as the student-facing

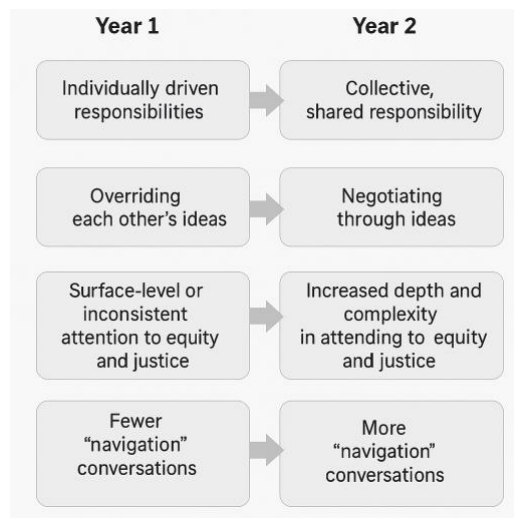
materials were grounded in a shared pedagogical rationale. With the unit's focus remaining essentially unchanged and the planned decision-making processes expanding the depth and clarity of expectations, the team operated from a more aligned position.

Part B: Changes in the Team's Pedagogical Responsibilities

Throughout the 2-year partnership, shifts emerged within the team's discursive conversations around how they defined good and equitable teaching. For the team, this involved refocusing their responsibilities away from an access-based focus, linguistic supports, and scaffolds toward the development of explicit activities that addressed awareness and action in civic engagement. Examples of these design shifts were presented in Part A, which highlighted some of the more prominent conversations that led to the observed shifts in planned pedagogical actions. Notably, such shifts in planned actions result from the decision-making processes that govern them (Horn & Garner, 2022). As such, understanding the rationale behind these changes to the planned pedagogical actions required illuminating the pedagogical decision-making processes and responsibilities that undergirded them (Horn & Garner, 2022). Firstly, to ground this part of the findings section, I have provided a holistic overview of the changes in the team's collective reasoning and responsibility that emerged between the first and second years of the partnership project (see Figure 4).

Figure 4

Holistic Changes in Sensemaking Conversations Between the First and Second Year



While the collective shifts illuminated the changes in the sensemaking process around the co-design of their equity-centered unit, the individual teachers' pedagogical responsibilities and reasoning were considered the primary outcomes. To this end, it is imperative to foreground the changes in individual teachers' responsibilities, particularly for Patty, James, Nina, and Samantha. Here, I start by illuminating the patterns in individual teachers' pedagogical shifts within the team. I show the collective changes, further validating the holistic changes that emerged from discursive conversations. The teachers' individual interviews were conducted at the beginning and end of the partnership project, providing information about how teachers narrated equity, justice, and civic engagement individually, as well as how their responsibilities changed. Utilizing Horn and Garner's (2022) pedagogical judgment framework, I examined how the teachers defined good teaching and the criteria they considered essential to illuminate their pedagogical responsibility at different stages of a 2-year journey (as shown in Table 4).

Table 4

Overview of Individual Changes in Pedagogical Responsibilities

Teacher	Year 1	Year 2
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	Good teaching	Defining justice	Good teaching	Defining justice
James	Translanguaging for scientific sensemaking.	A direct relationship between classroom and community learning should be intertwined.	Repositioning students as experts within the field of science.	Climate justice involves supporting students in developing their awareness and action.
	E.g., “I want to make sure that there’s a space created for them where they can access and use those languages when making sense of scientific concept.”		E.g., “it had started up within the individual awareness, and some students are to bridge out towards like collective action,”	
Samantha	Developing students’ skills as scientists.	Science should be relevant and incorporate students’ backgrounds.	Foregrounding students’ interests, motivation, and background in driving the learning experience.	Climate justice involves supporting students in developing their awareness and action.
	E.g., “If you can learn the skills of science, or just being a student or doing stuff in class, you can do any other subject and do just fine more.”		E.g., “The students now understand they do have a voice that they can use... I did like bringing civic engagement into science. A lot of times you only hear it in social studies, and that’s where everybody always wants to put it.”	
Nina	Equitable grading practices and providing accommodations.	Diverse and appropriate representation in science and school is critical.	Foregrounding students’ interests, motivation, and background in driving the learning experience.	Science instruction needs to support students in developing personal, cultural, and historical connections.
	E.g., “The first thing that it as far as equity goes, I’ve been really looking at my grading practices and changing last year with my AP students.”		E.g., “The fact that students looked at their own campus and saw things they wanted to change on the campus in relation to biodiversity and science, and they got to choose who they worked with.”	
Patty	Providing equitable supports and scaffolds.	Diverse and appropriate representation in science and school is critical.	Foregrounding students’ interests, motivation, and background in driving the learning experience.	Planning and development of science curriculum needs to foreground equity and justice.
	E.g., “I think a lot of students are scared to share in science classes because they don’t feel that they have the academic language and or the academic-right-language.”		E.g., “Like, it just felt like we were checking off a skill that we thought was important to have versus a more genuine approach of educating and supporting our student learners.”	

The analysis of teachers’ responses revealed several findings regarding shifts in the conceptualization and alignment of their pedagogical responsibilities, as seen in how they

defined good and just teaching. Firstly, at the beginning of the partnership, Patty, James, Nina, and Samantha centralized differing conceptualizations of good and just teaching when asked during their initial interviews. For example, data from Table 4 revealed that Patty and Nina centralized representation and inclusion within science, James focused more on the community-classroom connection, while Samantha paid more attention to the relevance of the curriculum. Critically, while the teachers' definitions are grounded in varying conceptualizations of equity and justice, what they foregrounded varied among them. Additionally, their definitions grounded notions of representation and supports/scaffolds as primary elements of equitable work, illustrating commitments focused on accessing science rather than using it as a tool for disruption.

Comparatively, in their final interviews at the end of the second year, Patty, James, Samantha, and Nina's conceptualization of equity, justice, and civic engagement expanded beyond their initial focus on access and representation. In terms of defining these constructs, a common trend that emerged across their responses was the importance of supporting students' awareness and action to authentically engage in civic-centered action. This was more evident in James' response, where he explained the importance of developing awareness of these local issues and subsequently taking action against them. Stating that "it had started up within the individual awareness, and some students are to bridge out towards like collective action." Moreover, his conceptualization of awareness and action was not singularly his; it was shared by the team and emerged in each of their interviews.

Over the course of the second year of the partnership project, the team's conceptualization of what they define as good and just teaching not only expanded but also became more aligned among themselves. This can be seen in other team members' responses,

with Patty, who highlighted this evolution in understanding by directly addressing the importance of moving away from schooling as a form of “checking off the boxes.” Instead, teachers need to have a more “genuine approach to educating our children.” Similarly, Samantha explains the need to attend to students’ voices in the science classroom, highlighting that, traditionally, this work takes place in social studies classrooms, not in science. Each member of the team is simultaneously highlighting the expansion of their own understanding while demonstrating the shared responsibility they were working from at the end of the partnership project.

To provide further insight into the depth of these shifts, below I begin by illuminating the individual changes in pedagogical responsibility for equitable science instruction. Then I attend to the process by which these individual shifts occurred, highlighting the structures and relationships within the professional learning setting that contributed to this collective evolution of discourses.

Beginning of Year 1: Collectively Committed to Equity and Justice, But Working Towards Different Ends

From the outset of the project, each team member expressed a deep sense of responsibility toward equity, justice, and civic engagement; notably, these responsibilities were rooted in commitments that both aligned and competed. While the teachers were all committed to enacting equitable science instruction, their differing conceptualizations highlighted alignment issues that could affect the teacher’s enactment of the unit’s intended outcome. Towards this end, when team members were asked individually during their initial interviews how they defined equity, justice, and civic engagement, Nina, James, and Patty converged on a unified definition: the importance of diverse representation in science classrooms. Nina specifically stated that, “a lot of students don’t see themselves in science because many of the textbooks and examples are

white dudes.” Here, she called attention to the issues of representation in the science curriculum, highlighting the stereotypical representation of scientists as “white dudes.” Similarly, but also on a more localized level, James elaborated on this idea by providing a justice-based example currently occurring at his school site. In the past year, students and staff had attempted to change the mascot because it did not accurately reflect the local community’s cultural capital and diverse history. Although these two examples from the teachers highlighted levels of convergence, they also illuminated nuanced points of divergence that continued to emerge across the members’ initial responsibilities.

When the team members elaborated on what equitable and just practices could look like in their classrooms, their responsibilities centered on different conceptualizations of equity. Starting with Nina, she explained that equity involved enacting “equitable grading practices” and creating supports and accommodations that increase students’ access and opportunity. Similarly, James and Patty centralized including supports and scaffolds that valued and respected students’ linguistic capital as a central pillar of equitable instruction. Patty explained this responsibility towards multilingual students who were “scared to share in science classes because they don’t feel that they have the academic language and or the content academically-right-language. And so it’s like your ideas and how they come out of you are just as important.” She highlighted her commitment to creating a space where students could express their ideas in ways that valued and respected what they brought forth, rather than molding them to specific norms and standards. Similarly, we saw James express a sentiment that aligned with Patty’s, emphasizing the importance of supporting students’ linguistic capital within the classroom. Both Patty and James demonstrated alignment in their conceptualization of equity as a form of knowledge heterogeneity, as well as in their emphasis on equity of access and opportunity.

Necessary to this alignment was the shared professional background that Patty, James, and Nina had throughout their careers. Firstly, Patty and James held a multilingual science certification and taught designated multilingual classes. They had been explicitly trained in translanguaging practices through their district or pre-service education programs and had collaborated on this in the past. This gave them camaraderie and a shared pedagogical responsibility that was not visible between other team members. Patty explained, “I provide lots of opportunities for my students to approach projects and to showcase their learning in different ways that are equitable to them as an individual.” Towards this end, Nina had worked with Patty and James in a district summer program designed to support district multilingual students in language development. However, she did not possess the multilingual certification and had not been trained in translanguaging practices. This deviation in professional background emerged as a point of divergence in pedagogical responsibility, as Nina highlighted more general pedagogical actions rooted in equitable grading, rather than actions specific to multilingual students. Although all three were committed to enacting equity and justice in their classrooms, the specifics of their focus varied.

On the other hand, Samantha, new to the team, highlighted a pedagogical responsibility rooted in experiences not shared with the team. Samantha, who was finalizing her Master’s program at another local university, explained that these topics of equity, justice, and civic engagement aligned with her coursework. She explained that civic engagement was not a focus in science at her school, but was emphasized in social studies. Taking issue with this, Samantha explained that science education should encourage students to advocate for themselves and focus on topics relevant to their lived experiences. She explicitly highlighted problems with the local bird population and its decline in California. Notably, Samantha was not the only one who

highlighted making the content relevant as a vital equity move. James also emphasized the importance of “relevancy.” Still, his responsibility diverged from Samantha’s in that he highlighted community-centered science learning. Ultimately, this illustrated a deviation in commitment when focusing on relevance within the science curriculum, with Samantha emphasizing localized ecological importance and James attending to localized community connections. While both were committed to making science relevant, the focus of that relevancy was quite different.

Although the team converged on many points within the constructs of equity and justice, they also diverged, resulting in competing responsibilities that informed the unit’s design. This divergence was made salient during James’ initial interview when he explained, “I am still curious, though, because, as I was kind of listening to Patty and Nina and everyone else, I want to see how their perspectives are, because I think they might have a different perspective than I do.” He acknowledged that his team members had different views, which informed how they rationalized the unit’s purpose. This comment addressed the differing contexts of the teachers’ schools and how they conceptualized their support for students seeking to understand their connection to historical land use. Later, he explicitly stated that,

we know for a fact, we were not the first group of people that were here, and because many of the students are Latinx, they have experience with being a part of different groups of people who have not necessarily lived in that same land since the beginning.

James illuminated his commitment to historical knowledge and experience, but his responsibility was not currently aligned with that of the other members. While he did not elaborate on this difference in perspective, his explicit attention to these divergent responsibilities highlighted their salience in the team’s initial conversations.

End of Year 2: From Competing and Diverging Responsibilities to a Shared Collective Commitment Towards Civic Engagement

Over the next 2 years, shifts in the team's conceptualizations of equity, justice, and civic engagement emerged through their discursive conversations. Revisiting Table 4, it can be seen that there was greater alignment among individual team members in how they defined good teaching, as well as equity and justice, in their interviews. Collectively, two prominent patterns emerged across the four teachers. The first was a focus on the heterogeneity of knowledge within STEM, whether through the student-driven nature of the capstone projects (culminating project of the unit) or through explicit attention to community and indigenous knowledge. The teachers collectively demonstrated a concerted effort to attend to and leverage knowledge beyond explicitly established STEM. The second was the aligned commitment to supporting students in becoming aware of historical and current injustices and in learning how to address them. They highlighted these as focal responsibilities within equity, justice, and civic engagement, addressing relevant localized problems facing students and their communities. These shifts indicated a more concerted effort by the team towards shared responsibility, which was further reinforced by the fact that only one Year 2 teacher did not participate in the community walk with their students when two new team members were added.

While the above patterns illustrated a broader shift over the 2 years, individual teachers also experienced visible changes. In terms of personal changes, while James continued to foreground the community-centered nature of his responsibility, he emphasized the centrality of students' action and awareness. However, this evolution in pedagogical was is illustrated in his shift in reasoning, where he explained,

what I think about is the act of taking like civic action can be very intimidating to students who are not familiar with the environment, especially if you're living in an area where sometimes immigration is a very politically charged topic.

He explained his awareness of the consequences and challenges of doing this work with students whose families, especially those from migrant backgrounds, might face pushback as a result of their participation. Wanting to provide a safe, civic-centered environment, he foregrounded diverse ways for students to participate in this work that felt comfortable to them.

Like James, Samantha and Nina foregrounded the importance of supporting students in developing their awareness of injustices and in enacting actions that explicitly addressed them. Both emphasized that students' motivations, interests, and voices needed to drive this work throughout the process. Nina emphasized the agency students had in this unit: "the fact that students looked at their campus and saw things they wanted to change on the campus about biodiversity and science, and they got to choose who they worked with." Her statement foregrounded the importance of students' agency and autonomy in the decision-making processes relevant to issues on their campuses (through doing the campus walk). Meanwhile, Samantha focused more on the perception of students being seen, not heard, and "understanding that they do have a voice that they can use." She explicitly emphasized the importance of students using their voice and ability to vote to effect change that impacted their communities. Although Nina and Samantha emphasized different elements of students' agency, they were aligned in repositioning students within the unit's design. Furthermore, there was greater conceptual alignment than in the language they used 2 years prior.

On the other hand, Patty explained that she did not feel like she grew as much as everyone else. Notably, Patty stated this because she transitioned from a teacher role to the district office in the middle of the year while continuing to work with the team. She elaborated on how the partnership had reshaped her approach to collaborating with other teachers, leading her to a more concerted effort to attend to equity, justice, and civic engagement explicitly.

Although Patty perceived that she had not changed, her response illustrated an aligned understanding with the team about the importance of classroom curricula in fostering students' awareness and action against injustices.

Across each team member's responsibilities, patterns emerged in the language the teachers used to define equity, justice, and civic engagement, as well as the pedagogical actions that encapsulated their conceptualizations of these terms. To illustrate, the team highlighted the criticality of equitable and just instruction, foregrounding awareness and action that addressed localized forms of injustice. To achieve this aim, the teachers needed to support students in developing their understanding to formulate actions that addressed these issues. Notably, the team's language positioned students as agents of change within this process, illustrating the substantial role of their autonomy. While there were variations in their conceptualizations, which was to be expected, a far greater level of alignment was present compared to the beginning of Year 1.

Transitioning From Individual Shifts to Collective Changes in Sensemaking Processes

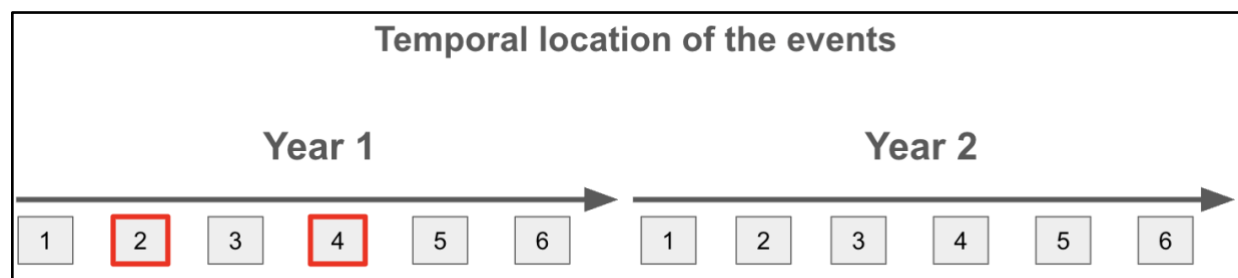
These individual changes in responsibility were the result of numerous discursive conversations that occurred over the 2 years of the partnership project. It was within these moment-to-moment interactions that the team engaged in sensemaking conversations that shaped and were shaped by their evolving conceptualizations of equity, justice, and civic engagement. In line with the shifts in individual responsibilities between Years 1 and 2 of the partnership project, the ways the team navigated these sensemaking processes also changed. Towards this end, two prominent shifts emerged in discursive sensemaking: (1) there was a move away from individually-driven responsibilities that guided the unit's design to a collectively-shared responsibility, and (2) there was a shift in collective sensemaking from overriding each other's

ideas to negotiating through them. Overall, the team shifted from being individually committed, working with differing responsibilities and reasoning, to collectively committed with a shared responsibility that informed an aligned pedagogical reasoning. To illustrate this, I will juxtapose two events from each year for each shift to illuminate the changes in sensemaking processes that informed the modifications in design and conceptualization.

Shift #1: Moving away from individually-driven responsibilities to a collectively-shared responsibility. In the first year of the partnership project, the Living Earth team developed a unit that attempted to encompass the expansive responsibilities of each member, but they struggled to define its overarching purpose due to the complexity of the navigation process. On the other hand, during the second year, the team reflected on the issues and challenges that had emerged previously, collectively committing to a shared vision that yielded a unit that had a targeted purpose and design. Towards this end, in the first year of the partnership project, the team's sensemaking conversations focused on the emergence of their responsibilities, rather than on navigating them. As such, during discursive conversations, shared pedagogical reasons or collective decisions that informed the unit's outcome and design were not discussed. Meanwhile, in Year 2, after the team enacted and reflected on the data from Year 1, these collective decisions stemmed from a renewed, shared commitment, driven by the teachers' reflection on the enactment (see Figure 5).

Figure 5

Year 1: A Unit Driven by Differing Individual Responsibilities and Reasons



In the first year of the partnership project, the team struggled to reach a shared consensus on the unit's collective focus and objectives. As seen previously, Patty, James, Samantha, and Nina were each individually committed to equity, justice, and civic engagement, but foregrounded differing conceptualizations at the onset of the partnership. In addition to these differences, the team was simultaneously navigating conceptualizations, modeled by the facilitator, that focused on disrupting power hierarchies, a conceptualization that had never collectively or individually emerged before this point. As such, during the team's initial share-out of their unit's commitment at the end of the first PD, they explicitly stated that "supporting sense-making, attending to race, language, identities, and disrupting power hierarchies" were their focus principles. The team had selected these three principles from the five options presented earlier in the day: (1) making it matter; (2) supporting sense-making; (3) attending to race, language, and identity; (4) building a welcoming community; and (5) disrupting power hierarchies. While the first two commitments aligned with responsibilities they had previously discussed, disrupting power hierarchies was new and emerged shortly after the facilitator modeled her own equity commitments.

With the inclusion of this new conceptualization of equity, the team developed their overarching commitment to "transform[ing] science learning for culturally sustaining, globally

and ecocentrically minded citizens.” To support their unit’s overarching commitment, the team established underlying principles that guided this focus. In line with the principle of disrupting power hierarchies, they argued that “students must see that there is no ideal look for a scientist” because diversity in science means diversity in ideas and solutions. This drew directly on their established individual responsibilities, which focused on representation and diversity as paramount to science education (as seen earlier). Here, they discussed the importance of heterogeneous forms of knowledge and shared a “desire for my students to leave my classroom feeling confident about their science background and with a strong science identity.” Notably, when they explained their rationale behind this conceptualization, Patty, along with Nina and Samantha, emphasized the importance of students developing their “science identities.” This conceptualization of “science identities” was later defined when James explained that students should feel that they belong in the science community, which can give them the confidence to express their “racio-linguistic richness” in their sense-making processes. Notably, this language emphasized the professional backgrounds of Patty, James, and, to a slightly lesser extent, Nina. Since Patty and James were the multilingual teachers, the focus on language and identity drew significant attention to their responsibilities.

When the team discussed these principles and elaborated upon them with their examples and commitments, the distinctions were not clear. Specifically, in their conceptualization of disrupting power hierarchies, they focused on students’ presence and feelings of acceptance within the science community. At the same time, when they discussed sensemaking, they highlighted a similar principle, with students “feeling confident with their science background” to illustrate a connection between their identities and the ways they came to learn about science. However, this lack of distinction between the principles highlighted the team’s struggle to

articulate and define what disrupting power hierarchies looked like in practice. When we considered that a focal element of the team's commitment was "transforming science learning," we did not see a clear indication of the roots of this language in either their discursive conversations or written commitments.

As a result, the lack of distinction amongst their chosen principles highlighted a potential misalignment. This was further substantiated by the team's selection of three equity principles to guide the unit's focus, which they struggled to differentiate when engaging in sensemaking through them. Their equity commitment involved the "transformation of science learning," a conceptualization deeply rooted in the disruption of power. Significantly, the language that they were using did not stem from their individual responsibilities, but instead from them taking up the facilitators' shared responsibility. While there were distinctions between their own and the facilitators' aims, the shift from using "sustaining" to "culturally sustaining" highlighted a more racio-linguistic approach (a focus of Patty and James), the focus of transformation of science learning parallels. However, even though the team consistently highlighted this conceptualization as a focus, it rarely emerged in subsequent conversations. This implied that the team was heavily drawing upon the facilitator's responsibility to understand this construct while attempting to maintain it as a foundational responsibility of the unit.

This complex process, in which the team attempted to embed the pedagogical responsibility of disruption while also collectively navigating its meaning, was further illustrated as the year progressed. In a subsequent PD session held around three months later, the team presented progress on their unit's current iteration to the entire group. It was during this share-out that I saw the team continue to emerge with distinct conceptual foci for the unit's design, with no one idea taking precedence over the others. The lack of shared responsibility within the

team led to unclear reasoning and decision-making processes that informed the structure and design of the unit's components. When the team shared progress on their unit, they described their capstone as a "call to action," noting their intention to make it action-oriented; however, they had not yet reached a final consensus on its overarching design. Here, it was seen that their action-oriented focus stemmed from their prior youth participatory action research (YPAR) work experience. Importantly, their collective reasoning not only drew on the shared reasoning of their facilitator (who worked with them extensively a month earlier, as seen in shift #2), but also on their own prior professional experiences to make sense of practices that were non-traditional and new to them.

13:37 James: So, for the capstone we haven't fully fleshed it out yet. The idea is that students are working on a call to action to share to their community members as, how can we as a community start changing the ways we use the land to better address the climate change that we are currently facing directly in our community? Am I missing anything?

14:10 Samantha: Just going back to that thing about leaving a story behind, we aren't going to see it, our grandkids may not see it, but years from now we will be looking at old photographs of things and it will be looking back. What do you want permanently written about your generation that you can't change anymore?

14:46 Facilitator: So you, some of those parallels between this team's design and a lot of like similarities between, you see, future orientation is something that I see common, but then here a lot of like storytelling about the people who live there. So, they are diving into the people who live within these communities. So cool, okay, so how can we make this unit even better? Share your thoughts, any questions, wonderings?

15:35 Teacher (off-screen): I have a question. You have images of 1938 and 1935 as your starting points and I wanted to know why. But I also, the second question is, on the thinking of the future, how do you encourage them to think about new inventions instead of returning to the past?

15:57 Patty: We actually conversed about the topic of bringing in our land use by communicating indigenous...

16:03 Nina: We were going to include that but somehow this didn't get, so we are going to go back to perhaps look at how the [indigenous] people actually used it before us and how it was focused on sustainability and so looking at how can we do those practices and look at sustainability as well.

00:12 Patty: So those shift by the influx of immigration and so then our immigration stories which I think is really important for our students to see how the different population came in and changed it (shares specific example from local community). Those types of components keep coming up and then I think we put those specific ones because they are more broad and open. So, we had diverse points for them to talk about.

1:09 Nina: We wanted to make sure that they were focusing on something that they were really familiar with so that they would have some ownership and this is what it looked like, so let's go back back back, but not right away.

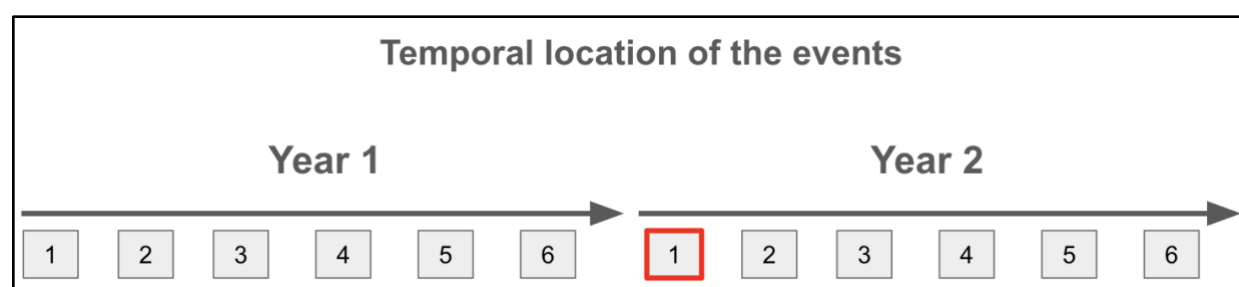
This uncertainty and sensemaking were further illuminated by the team's response to the teacher's question about using photos and about the represented periods. Patty explained that they were trying to bring in indigenous people when Nina interrupted to say that they did not include indigenous people's sustainable practices but wanted to, and asked students to consider how they could utilize these practices for potential future solutions. Patty then transitioned to the broader immigrant community and their connections to land use, moving the conversation away from indigenous knowledge and practices. The team had taken responsibility for making the capstone project student-centered and action-oriented, as this aligned with their shared responsibility with the facilitator and their prior professional experiences in YPAR. Here, there was less agreement among the historical community, with Samantha highlighting individualized student stories, Nina focusing on indigenous practices, and Patty concentrating on immigrant populations. The team's individual pedagogical responsibilities seemed to directly conflict with each other, resulting in an unclear focus.

In the end, these unresolved tensions and competing pedagogical responsibilities and reasons resulted in a unit that the team was proud of, having worked incredibly hard to develop it, but they also felt it had "died off" during its enactment in their classrooms. This perception emerged during the final PD of the first year, which took place weeks after the units had been conducted in their classrooms. During that PD and the team's reflection, Nina, Patty, and Samantha explicitly stated that they had been unable to achieve the unit's intended goals and that

it “started strong” but did not end where they had wanted. Structurally, this highlighted that the team felt that the start of the unit, where the indigenous reading and analysis of historical land features were located, was stronger than the end, where the capstone was located. This team reflection, that the unit had “died off,” highlighted their awareness of the gap between their pedagogical responsibilities and the planned actions they had employed in the unit’s design. Notably, this perception was a focal point the team drew upon during the second year of the partnership, as a renewed collective responsibility (Figure 6).

Figure 6

Year 2: Operating From a Collectively-Shared Pedagogical Responsibility



The following year, at the beginning of the fall semester, the partnership project resumed with its first PD session, which was held over two days at the start of the school year. As in the first year, the PD started with introductions, since new members had been added to each team and some members did not return. For the Living Earth team, no members had left, but two new members, Rob and Elisa, were added. Elisa taught at a school near Patty, while Rob taught at a school on the other side of the district, which some team members perceived as being in a wealthier neighborhood. Because of this, team members believed that Rob’s students and instruction would differ, requiring less support and scaffolding. It was essential to note this dynamic, as Rob’s years of experience in the district positioned him as a veteran and may have made team members more hesitant to challenge some of his decisions.

In the first PD of the second year, the team focused on catching Rob and Elisa up on the work done during the previous year. This was the first time the Living Earth team had discussed the overall purpose and outcomes of the co-design unit. At this time, Patty attempted to catch up with Rob and Elisa and wanted them “to be conscious of what went into” the unit’s design. Patty described the activities and assessments, but then returned to areas they wanted to improve in the unit:

40:02 Patty: So, we need to be fix the social justice component. We all noticed it last year, and then what else?

40:10 Samantha: It started off strong but then it kind of died off...

In comparison to the language Patty used the month prior, when reflecting on the unit’s implementation, her perception had shifted from rejecting the previously identified gaps to foregrounding them. The rationale behind this decision drew from Samantha’s perception that the unit had “started off strong, but then it kind of died off” when implementing social justice within the unit’s design. What emerged here was a concerted responsibility by the original members to improve the unit’s overarching approach to social justice. At this moment, Samantha and Patty acknowledged the areas for growth from the prior year, but then shared this responsibility with the new team members. This alignment in reasoning directly contrasted with what was seen months prior, indicating a potential shift in their sensemaking processes.

As the PD continued into the second day, the facilitators had teams transition into their co-design work time. For the Living Earth team, this conversation continued where they had left off previously, analyzing the unit’s scope and sequence. Patty initiated the conversation when she asked the team about the driving question, asking if they want to “shift away from the historical timeline?” This prompted the team to reflect on the historical connection within the unit’s design and how it supported students in developing their awareness and action towards

localized injustices. Their discussion illuminated a potential shift in their responsibilities from the previous year, where instead of centralizing standards-based mastery, they foregrounded students' awareness of colonization. In the following interaction, we can see how the team refined the unit's focus, shifting from merely supporting students' awareness of historical injustices to a future-oriented action plan.

25:02 Patty: Do you want to shift away from the historical timeline?

25:54 Nina: Well, but looking at I think the past is really important and the students really mind made a connection with the [local indigenous community] had this land, it was stolen from them. Like, this isn't okay. Like almost if they did acts like digital justice, like an action plan where, or like PSA or informational thing.

26:45 Facilitator: But that could be one of the main projects that they choose to do.

26:52 Nina: I feel what you're saying for that, for them to practice social justice without like putting themselves out there because they're not going to give us the time and they can't go back in time. They're creating something if we could, but their audience isn't there in the system. When we did the capstone project, we actually had them find an audience. That means that they're trying to find like a hypothetical one, like talk to like the commissioner, talk to the settlement to talk to this. But I'm just trying to keep that piece part of it because if they were mad, they would ask me about how the land was stolen from them.

28:08 Rob: Technically they're caretakers of the land. They didn't own the land, right?

28:10 Nina: I agree. So caretakers of the land, what's the difference between a caretaker and an owner?

28:29 Rob: I think it's still fine to start with that. I mean, right, historical time, if you have to know where you came from and now we buy where we are. (Nina talking at the same time)

28:41 Facilitator: But I think, and that could very easily be something they want to pursue further, too.

28:50 Rob: Yeah. There might be someone that really wants to delve into indigenous people.

29:02 Patty: Like using history to make social justice changes to our future communities.

29:16 Facilitator: What if it was awareness of historical injustices? To inform, to inform?

29:25 Patty: To inform your actions?

29:31 Facilitator: Yes.

30:09 Samantha: What if it was towards the land, what if it was towards the people? Buildings?

Importantly, this interaction occurred after the team participated in a teacher-led presentation on supporting students' awareness and action in their capstone projects, a point that is explored further in Part C. In this interaction, Nina, the first to respond to Patty's question, explained that it was "not okay" that the indigenous people's land had been stolen from them. She explicitly stated that she wanted students to feel "mad" about the historical injustices of colonization, emphasizing her rationalization for the continued inclusion of this focus on historical timelines. Patty extrapolated on Nina's responsibility and shifted the focus from awareness to action by "using history to make social justice changes," a shift the facilitator and she highlighted as "informing your actions." Furthermore, as this conversation continued, the team further elaborated on their driving question, inquiring whether they wanted to include the word "sustainable" in their driving question. Notably, the language the team used here highlighted a concerted responsibility towards addressing students' awareness and action of injustices, as opposed to their mastery of standards-based science skills.

This interaction, which took place around nine months after the previously illustrated event, highlighted a fundamental shift in their responsibilities. In the first year the team had simultaneously been navigating their own competing responsibilities, along with the new ones presented by the facilitators. As a result, the equity language used during their previous conversations was often general and did not have an explicit focus on what equity and justice would look like in the planned pedagogical actions. However, in the second year, the team was no longer competing with each other's responsibilities; instead, they were collaboratively

negotiating what their collective responsibility would look like in action. This is seen in the prior example, where they explicitly worked together to define what “sustainability” would mean and look like within the design of the unit. Notably, alignment conversations like this did not emerge within the first year of the partnership project.

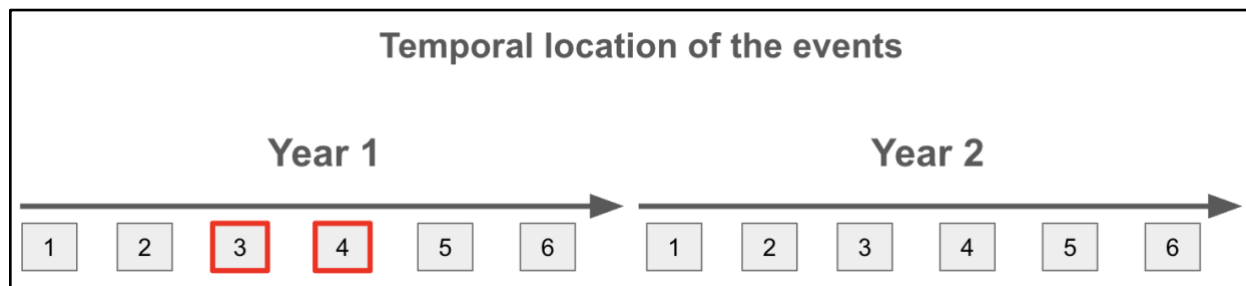
Instead, what was found during the first year was a team that was all deeply committed to the work of creating equitable classroom spaces, but from non-aligned responsibilities. This mismatch in responsibilities produced numerous tension-ridden events, where the team was attempting to override each other’s responsibilities rather than navigate them. Critically, this changed during the second year, but illuminating the contrast in their sensemaking processes was critical to understand how and potentially why the team changed over the course of the 2-year partnership.

Shift #2: From overriding each other’s ideas to negotiating through them. Between the first and second years of the partnership project, a key difference in the sensemaking conversations was the way the team engaged with and negotiated through their differing responsibilities and reasons for their planned pedagogical actions. In the first year, the team frequently employed a sensemaking tactic of overriding each other’s reasoning and responsibilities during instances of tension and conflict. In these instances, I use the term of *overriding* to refer to interactions where one individual’s judgment was foregrounded over others’. During these instances of overriding, the team would not follow up or negotiate through these tensions or disagreements; rather, one person’s responsibility and reasoning was perceived as having been adopted by the others. The team then moved on, without following up on these perceived agreements.

Importantly, the lack of resolution among the team members may have been a foundational reason the team perceived the unit to have “died off.” Moreover, the team had also perceived high levels of misalignment among themselves in enacting the unit with full intentionality. On the other hand, during the second year, there was a significant decline in the frequency of overriding, and instead, negotiation emerged as a predominant tactic. Here, rather than a single person’s judgment being foregrounded, the team pushed back on each other’s reasoning and responsibilities through questioning and compromising. The stark contrast in sensemaking processes illuminated a potential shift in the team’s collective alignment of their pedagogical responsibilities. Instead of a team attempting to compete for whose responsibility should be centralized, their increased involvement implied a level of sharedness that had not been present previously (Figure 7).

Figure 7

The Overriding of Responsibilities and Reasoning During the Unit’s Initial Development



Overriding emerged in numerous events during the first year. It involved not only decisions that shaped key design features of the unit, but also commitments that undergirded its entire premise. To illustrate this, I analyzed an event from the third PD session of the first year, during which the team met over Zoom to focus on developing their unit’s capstone and gapless explanation. Before this event, the team had finalized their essential question (the one presented in Part A).

The meeting began with the facilitator asking the teachers, “What are you proud of in the unit’s design?” James, Nina, and Samantha explained that they were proud of the community and student-centric nature of the unit, highlighting the focus on indigenous tribes. At the same time, Patty did not provide a proud moment; instead, she used that time to explain the importance of the team identifying the relevant state standards for their unit. Subsequently, this prompted a conversation with Patty, leading to a discussion of the need for the unit to properly assess students’ understanding of the Next Generation Science Standards (NGSS). Her emergent responsibility within this moment was to ensure that the scientific concepts aligned with the district’s initiative, as well as with their curricular scope and sequence. This interaction highlighted the competing responsibilities among team members and how overriding occurred as a form of sensemaking during the first year.

28:31 Patty: So that is every point across districts, and so even though we are all teaching at different sites, we wanted to make sure we are honoring our scope and sequence, and especially since Nina and I swap back and forth with kids all the time, so it is just beneficial for us to look at that. That was our point for where do we want to start, how long do we want to take this? And then from there we built out.

28:58 Facilitator: So then do you agree, do you feel comfortable to say that addressing all of these DCI, we are going to group it? Addressing all of them is our goal for the six weeks... Because it seems to me the later three are more engineering focused. Defining engineering problem, developing possible solutions, optimizing design solutions... if that is the goal, then this seems to me to really be about engineering. We have to ask students to be engineer, to be a designer, design their community [small laugh], design the MACC, design their school garden.

29:45 Patty: Maybe not ETS1A because I need to look further in. I don’t understand that, umm...

29:51 Samantha: Well, I think that A and C would be the ones we take out. B, though, I think if we are having them look into the future, that would be a possible solution, right?

30:04 Patty: Wait, you have a point, optimizing the design solution. Yeah, they have to first have a solution to then optimize it so that we can eliminate those two .

30:13 Facilitator: You know to think about the solution, they have to define the problem.

30:17 Patty: Mhmm.

30:19 Facilitator: And then the problem that we tried to draw upon is the land use, some problem associated with the land use... and I also see that biodiversity and humans and adaptation and ecosystem, right? And if we wanted to bring this biodiversity, ecosystem then, in relation to land use...

30:52 Patty: That totally plays into the first wave of our plan, which is like, prior, current, and future and in our prior histories the diversity of the land was different, like the swamp in Apple County.

Within this interaction, Patty's responsibility directly competed with the other three team members, shifting the conversation away from what they were each proud of and toward standards-based alignment. While Samantha contributed midway through, the primary interaction was between the facilitator and Patty. In this key decision-making process, Patty's pedagogical reasoning was foregrounded, particularly because this conversation stemmed from her emergent pedagogical responsibility to align the unit with the NGSS. Since this conversation stemmed from the emergence of Patty's pedagogical responsibility, her reasoning subsequently followed (Horn & Garner, 2022). Here, she specifically highlighted the need for the unit to align with the engineering standards, suggesting a solution-based unit approach. Although Patty and Samantha had discussed this before, James and Nina did not explicitly align with this focus. Furthermore, in this singular instance, the competing responsibilities emerged naturally and undergirded the sensemaking processes during the unit's development.

Importantly, this was not an isolated event; rather, it occurred numerous times throughout the first year, even moments later in this same meeting. The frequency of this sensemaking tactic illuminated how the planned pedagogical actions observed within Part A may not have been a product of the team's collaboration, but rather a result of individual members' reasoning at specific moments in time. Conversations from later in this same meeting indicated that James, Nina, and Samantha collectively overrode Patty's responsibility in lieu of the attending

facilitator's. This may have occurred when the facilitator questioned Patty's reasoning for including numerous engineering standards, to which Patty responded, "I don't know these standards and need to look them up." As the facilitator continued to pose questions to the team, she probed them about their rationale for including so many standards in such a short timeframe (4–6 weeks). To this end, the facilitator narrated her own reasoning, wondering if "there is any way we can create coherent stories throughout the six weeks of the unit, instead of siloes of different stories?" In response to this question, Patty provided her own reasoning, stating that they wanted to keep each learning experience siloed, giving students agency to decide which information would be relevant to their own projects. Drawing upon Nina and James' experiences with YPAR in the summer multilingual program, Patty attempted to substantiate her claim of keeping the unit siloed and refuted the notion that the unit needed to be a coherent story.

Patty's reasoning for keeping the unit's concepts siloed operated from the responsibility of giving students agency but in actuality reinforced the facilitator's reasoning. By supporting students' sensemaking through the explicit focus on connecting differing ideas, students are allowed to see how problems are interconnected with what matters to them (Kang & Nation, 2023). Notably, the inherent tension that emerged within Patty's own reasoning was a natural part of the sensemaking process in this work (Engestrom & Sannino, 2011). However, instead of the team reflecting on this inherent tension, they overrode Patty's reasoning, as seen when Nina interrupted Patty moments later. In that moment, Nina sought to address her struggles with enacting sensemaking practices in her own classroom. Her interruption in that given moment was a potential attempt at overriding Patty's current reasoning to seek out the aid of the facilitator. Here she explained that, "I'm struggling with getting the format done correctly, as well as the phenomenon and essential question. So I'm trying to be better at that. And that's why I joined

this group.” Nina was overwhelmed by the previous conversation and may have sought to override Patty, based on the facilitator’s reasoning.

Nina’s direct interruption of Patty’s reasoning illustrated a potential disagreement on her part and sought to override Patty by eliciting the facilitator’s reasoning to her own struggles regarding the pedagogical decision-making in student sensemaking. It was here that the facilitator stepped in and discussed the importance of students tracking their thinking as they engaged in numerous interconnected events presented throughout the unit. But, critical to this moment was how James followed up on Nina’s struggle to include his use of a summary table, a classroom activity designed to track student thinking over time. Notably, James’ pedagogical reasoning aligned with what the facilitator had discussed with Patty earlier about creating a coherent story across the unit. Seeing this connection, the facilitator encouraged James and Nina to consider the pedagogical action of the summary table and apply it to the unit’s overall design. At this point, Nina and Samantha explained that an important feature or activity in the unit’s design would be for students to track their understanding. Subsequently, this led James, Nina, and Samantha to adopt the pedagogical reasoning that the unit should be coherent rather than siloed.

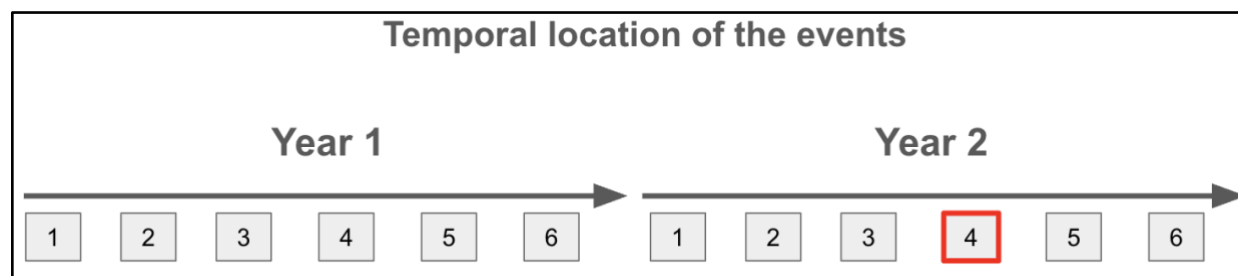
Importantly, we did not see Patty discuss this at the end of the event, as the team did not address her pedagogical reasoning for keeping the unit’s concepts siloed. Instead, James, Nina, and Samantha engaged with the facilitator’s pedagogical reasoning, overriding Patty’s. Returning to the team’s shared perception of the unit “dying off” or starting stronger than it had ended, this view could potentially have been connected to the prominence of overriding as a sensemaking tactic. In the instances when the team was attempting to sensemake through their unit’s design, they would often take up one or two individuals’ ideas, assuming that the rest of the team was on

board. As a result, when it came time for the team to enact the unit in their own classrooms, they drew on planned pedagogical actions that were not the result of shared pedagogical reasoning. Instead, these planned pedagogical actions may have been the result of specific members at different points in time. Thus, when it came time to enact, the individual members drew on their own pedagogical reasoning to plan pedagogical actions that did not align with their responsibilities. This misalignment between their collective pedagogical judgments and individual pedagogical judgments may have led to the perception that the unit had “died off.”

In contrast to the prominent sensemaking process of overriding that emerged in the first year, during the second year of the partnership, the negotiation of individual reasonings and responsibilities emerged as the dominant tactic (Figure 8). *Negotiation* was a term used to refer to the process in which emergent tensions and confusions were collaboratively discussed among the team until a shared consensus was reached by the majority of the members. Importantly, overriding did not outright disappear; in fact, it still emerged sparingly. However, even in those infrequent instances, it was no longer a single person’s reasoning that was being taken up, without subsequent conversations to process the statements being made. Overall, in the second year of the partnership, a greater sense of shared responsibility around the focus and design of the team’s unit seemed to have emerged. This sharedness was evident throughout most sensemaking events, even at the start of the second year.

Figure 8

Year 2: Sensemaking Through Navigation and Negotiation



To illustrate the shift in sensemaking between the first and second year, I call attention to an event that occurred in the winter quarter of the second year. Here, teams were tasked with creating their unit's activity sequence, in which they explicitly outlined the four or five key activities of the unit and the sequence in which they would occur throughout the unit's design. The purpose of this was for teams to make explicit what the key labs/activities were that students would engage in, and the order in which they would take place within the unit's design. Teams were tasked with creating guiding questions for each activity, summaries of what students would be doing, and explanations for how each activity was connected to the unit's overarching design (or the capstone project). For the Living Earth team, a focal activity or planned pedagogical action was for students to actively read and discuss a literary piece about the Apple County River. In this reading, the team created questions to support students in analyzing the lived experiences of local indigenous people. Explicitly, the team wanted to attend to indigenous people's stewardship of the land and to how students could learn from these practices to inform future land-use practices that would promote increased biodiversity. To do this, the team navigated through differing emergent reasonings, with members building on each other's language to construct a guiding question that the team collectively agreed upon.

23:21 Nina: OK, so do we agree that because the big thing for this project is for students to look at what the land was like in the past and how the [indigenous tribe] were with the land and how...

23:58 Samantha: How can... how can lessons from the past... develop... better... stewards.

24:06 Patty: Lessons from the past? (*Samantha looking up at Patty*)

24:09 Samantha: Well I mean the [indigenous tribe]...

24:11 Patty: Like historical?

24:12 Nina: Or how...

24:13 Samantha: Or something because she...

24:14 Nina: How do the [indigenous tribe], I want to make sure their name is in it...

24:16 Samantha: Right... how can... how can the stewardship of the [indigenous tribe] (*looking at Patty*)

24:23 Patty: How can we learn from?

24:25 Samantha: How did they demonstra... well umm... (*scrunches face looking at Patty, like she doesn't like her own wording*)

24:27 Patty: Let's think about the angle of the question.

24:31 Samantha: It is basically tied to this (*pointing at the food web component of the activity sequence*) because she wrote this basically off of that one (*pointing at the driving question*). I still think it works, it just, we need a question that does...

24:39 Patty: Okay... so... how can we model our decision? How do we model, blah?

24:55 Samantha: How can future policies... (*looking at Patty*)

24:57 Patty: How can future policies... or using the [indigenous tribe] people's...

25:02 Samantha: Land stewardship?

25:03 Patty: Land stewardship practices, how can we...

25:10 Nina: (*Arms crossed*) How can the relationship the [indigenous tribe] had with the land be used to guide us in our future? (*Samantha points at Nina in approval*)

25:14 Samantha: There we go.

25:15 Patty: There we go.

Within the sensemaking conversation, the team had to constantly negotiate the differing reasoning when constructing the question, as seen in the way Samantha, Patty, and Nina went back and forth in their attempts to refine the language of the questions. While Patty and Nina discussed, Nina paused and listened to their language, then built upon their ideas to construct the question she proposed. Notably, her proposition was met with immediate agreement by both Patty and Samantha, who used the unified terminology of “there we go,” with “we” being the focal point of collective agreement. Unlike the first year, these three were not attempting to overwrite each other’s ideas; instead, they were directly building upon each other’s language. This collective building resulted in the shared language “we” that both Patty and Samantha used to convey a collective agreement around Nina’s proposed language.

The language of this question can be compared to that of the one they had created a year prior, which stated, “What would it feel like? Or how would you feel after your land was taken away?” There emerges a clear distinction between the equity-centered focus of the first and second year. Mainly, in the second year, the team stressed the “use” of indigenous knowledge to inform future actions. The depth to which the team attended to the constructs of equity and justice had evolved significantly from their prior understanding of these concepts. The team initially focused on attending to how it would “feel” to have their [the indigenous people’s] land taken away from them. The team shifted the focus from awareness to action, with students analyzing how they could learn from the sustainable practices of indigenous people to inform their future actions. This highlighted a concerted effort by the team towards a pedagogical responsibility that was not only awareness-focused but solution-generating. Within this shared, aligned collective pedagogical responsibility, there was also a shared rationale for the design of the questions, activities, and structures that informed the unit’s design.

Although this shift illustrated an evolution in the team's overall understanding and conceptualization of equity, it illuminated a shift in how they sense-made through their pedagogical responsibilities to construct a refined pedagogical action. In the first year, the team was not operating under a shared pedagogical responsibility, as evidenced by the sensemaking process it engaged in to construct the question a year earlier. Unlike the transcript above, when discussing a year earlier, Samantha was the only one to push the team to include social justice in the reading: "part of me wonders if we want to throw the social justice aspect into it." After this, Nina and Patty discussed the previously described question without consulting Samantha, who had proposed the focus in the first place. The deviation in the team's sensemaking processes indicated not only an evolved understanding of equity-centered instruction but also a shared understanding of their governing responsibilities that drove their decision-making. To substantiate this claim, at the end of the partnership project, data revealed that four of the five Living Earth teachers had enacted the unit to its full intended extent, compared to the first year, when only half of them had enacted the unit to its full intention.

Part C: Understanding the Potential Connection Between the Partnership Project and Shifts in the Living Earth Team's Pedagogical Judgment

In the final part of the findings section, I seek to address the third RQ: how to understand the Living Earth team's evolution in sensemaking processes between the first and second years of the partnership project, as shown in both parts A and B. To do this, I sought to illustrate whether and how the Living Earth team drew on semiotic resources within whole-group learning experiences to shape their collective decision-making processes. The purpose was to highlight the connection between PD learning experiences and longitudinal changes in the Living Earth team's collective pedagogical judgment.

A total of 65 (28 in Year 1 and 37 in Year 2), 8- to 10-minute events emerged within the PD setting, during which pedagogical judgment language associated with constructs of equity, justice, and civic engagement emerged. Among these 65 events, 24 occurred during the transitory period between the first and second year, where prominent shifts in the team's pedagogical reasoning language were identified. In this section, I zoom in on 24 5- to 8-minute discursive events encompassing both whole-group and small-group conversations, focusing on shifts in language within and across settings. As previously discussed, I utilize Goodwin's (2018) cooperative action framework to guide the analysis of the team's transformation in pedagogical reasoning language, while tracing the interconnected nature of these changes with respect to the language presented within the professional learning experiences.

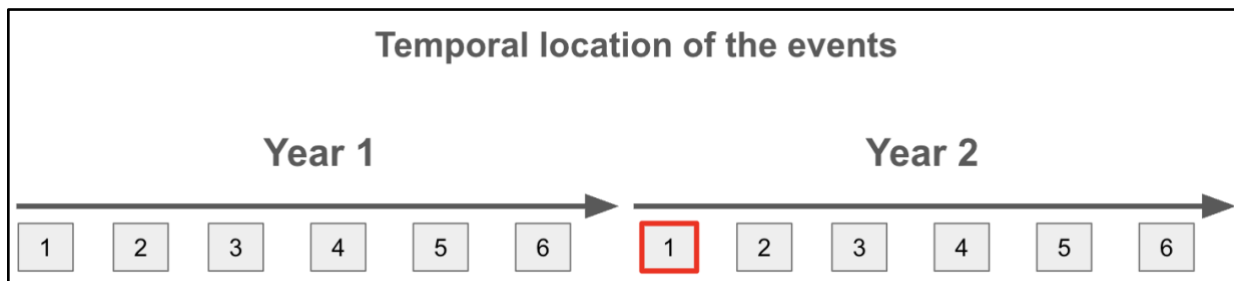
Through a comparative analysis of the whole-group PD events, facilitator- or presenting-teacher-led learning experiences, and the subsequent small-group Living Earth sensemaking conversations, a connection was found between the pedagogical reasoning language in both settings. Specifically, during the whole-group shared learning experiences, when teachers or facilitators made their pedagogical reasoning salient, the Living Earth team would often adopt decision-making language in follow-up sensemaking conversations. Across these 24 identified events, five distinct yet connected instances emerged in which the Living Earth team adopted language from the whole-group setting. Here, an *instance* is defined as a collection of 3-6 whole-group and subsequent small-group conversations. In each of these instances, unique language adoption patterns were identified between the whole-group setting and subsequent small-group Living Earth team sensemaking conversations. It was during this transitory period between the first and second year that the Living Earth team frequently used the shared pedagogical reasoning language to inform their subsequent sensemaking conversations.

However, analyses also revealed that this trend was not consistent; the frequency with which the Living Earth team adopted the shared pedagogical decision-making language was much higher at the middle and end of the partnership than at the beginning. This prominent variation in the team's adoption of shared pedagogical decision-making language prompted further analysis of the sensemaking conversations between the two time periods. Using Goodwin's (2018) cooperative action framework to trace the accumulation of language over time, along with Horn and Garner's (2022) pedagogical judgment framework to break down the elements of pedagogy, analysis revealed that a high degree of alignment in pedagogical responsibility or ideologies was needed for a transfer process to take place. In other words, when the team was not collectively acting from a shared pedagogical responsibility and the collective ideology was not aligned with the presenting facilitator's or teachers' ideologies, the likelihood of the team adopting the decision-making language was minimal.

To illuminate this transfer process, in the following part of the findings section, I first highlight what a successful transfer process looked like in the PD setting. Here, I zoom in on a PD meeting from the start of Year 2, where the team participated in teacher-driven learning experiences and where a prominent shift in language subsequently emerged. Then, to analyze differences in the transfer process, I compare and contrast two adoption instances at the beginning and end of the first year. The purpose is to illustrate how the ideological differences between teachers and facilitators shaped the team's collective engagement in shared pedagogical decision-making (see Figure 9).

Figure 9

The Transfer of Pedagogical Reasoning Between the Professional Learning Experiences and the Living Earth Team



Analyses revealed that during the transitory period between the end of the first year and two or three months into the second year, the team’s sensemaking language shifted prominently as they developed their co-designed unit. Specifically, there was a collective disappearance of language associated with supporting students’ mastery of standards-based science skills, and a simultaneous emergence of language that developed students’ “awareness” and “action” regarding localized biodiversity issues within their communities. Notably, across the whole group of professional learning experiences, both facilitators and presenting teachers used similar decision-making-based language. It was during this transitory period between the first and second year that the Living Earth team frequently used the shared pedagogical reasoning language to inform their subsequent sensemaking conversations.

The second year of the partnership project started with a two-day PD, with the first day featuring teachers participating in a model unit (similar to the first year) and the second day featuring presentations from teacher–researchers alongside planning time. There were two teacher–researchers’ presentations: the first, presented by Patty and Chris, was on the need for transparent expectations for students, while the second, by David, was on students’ awareness and action against injustice within their capstone projects. Linguistically, David’s presentation

introduced two new pieces of language into both whole- and small-group settings, resulting in the disappearance, emergence, and shift in language associated with pedagogical reasoning. Specifically, the terminology regarded supporting students' "awareness" of injustice and the "action" they would take, both at the individual and systemic levels. *Awareness* was defined in this context as not only observing but also recognizing inequity and injustice through a comparative lens. *Action* took the form of students explicitly engaging in ways to address these inequitable or unjust issues. An example that the teachers discussed was having students develop posters around the school about farming practices or petitioning for increased green landscapes.

A general takeaway from this presentation was that the Chemistry team's students primarily focused on their individual awareness and struggled to take effective systemic or community-level action. Afterwards, the facilitators had each team discuss these findings within their teams and reflect on their initial enactment, collaborating on ways to refine their units' designs. Subsequently, the Living Earth team discussed whether their unit should prioritize awareness or action, a distinction they had not previously made. Patty asked if the team wanted to "shift away from the historical timeline?" This prompted the team to reflect on the historical connection within the unit's design and on how it supported students in developing their awareness and action towards injustices. In the following interaction, we can see how the team refined the unit's focus, shifting from merely supporting students' awareness of historical injustices to a future-oriented action plan.

25:02 Patty: Do you want to shift away from the historical timeline?

25:54 Nina: Well, but looking at I think the past is really important and the students really mind made a connection with the [local indigenous community] had [with] this land. It was stolen from them. Like, this isn't okay. Like, almost if they did acts like digital justice, like an action plan where or like PSA or informational thing.

26:45 Facilitator: But that could be one of the main projects that they choose to do.

26:52 Nina: I feel what you're saying for that, for them to practice social justice without like putting themselves out there because they're not going to give us the time and they can't go back in time. They're creating something if we could, but their audience isn't there in the system. When we did the capstone project, we actually had them find an audience. That means that they're trying to find like a hypothetical one, like talk to like the commissioner, talk to the settlement to talk to this. But I'm just trying to keep that piece part of it because if they were mad, they would ask me about how the land was stolen from them.

28:08 Rob: Technically they're caretakers of the land. They didn't own the land, right?

28:10 Nina: I agree. So, caretakers of the land, what's the difference between a caretaker and an owner?

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28:41 Facilitator: But I think, and that could very easily be something they want to pursue further, too.

28:50 Rob: Yeah. There might be someone that really wants to delve into indigenous people.

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29:16 Facilitator: What if it was awareness of historical injustices... to inform...

29:25 Patty: To inform your actions?

29:31 Facilitator: Yes.

30:09 Samantha: What if it was towards the land? What if it was towards the people? The buildings?

Emergent within this event was the team's prevalent use of "action" and "awareness" language when making salient their pedagogical reasoning. The focus of this conversation was on determining whether or not they wanted to maintain or shift the unit's focus on attending to these historical timelines that had previously been foregrounded (during Year 1). However, unlike the previous year, the team was discussing how they could move beyond simply raising students' awareness of historical oppression to taking action against current injustices in their local neighborhoods. This could be seen when Nina reflected on Patty's question, then explained

that students needed to determine the primary audience for their capstone projects. However, as Nina continued, she went back to foregrounding the importance of attending to colonization and the feelings/emotions of the indigenous community, whose land was stolen. To this point, both Rob and Patty elaborated on the importance of supporting students' historical awareness to inform their future actions. It was here that the team collectively built on one another, drawing on David's shared language of "awareness" and "action" as a primary focus for their decision-making.

In this instance, the Living Earth team drew upon David's previously shared decision-making language and a prominent shift could be observed not only in the superficial language they used but also in the undergirding focus of that language. Here, the team's adoption of David's language went beyond mere use of the terms "awareness" and "action." Instead, the entire focus of their decision-making had shifted. Above, the conversation's premise was on sensemaking, specifically on whether they wanted to explicitly support students' "awareness" of historical injustices through the analysis of colonization. First, the team was making a conceptual distinction between supporting students' awareness and action. A focal component of David's learning experience was the opportunity for teachers to analyze different student work samples that demonstrated these distinct concepts. There, he explicitly discussed the Chemistry team's decision-making focus on supporting students' conceptual understanding of awareness and action, treating them as distinct elements. Subsequently, the Living Earth team was seen not only adopting the language of "awareness" and "action," but also as centralizing mastery as a focal element of the unit's design.

However, to understand the scope of this shift in the team's pedagogical reasoning language, I sought to contrast it with the verbiage and focus of the decision-making processes

used in a comparable event that took place months earlier, right before the teachers individually enacted their unit. This was the same event seen in Part B, Shift #2/Year 2, where the team was developing the questions for their historical reading on the Apple County River and focused on how the indigenous community “felt” when their land was taken away. During those conversations, a prominent pedagogical reasoning emerged, supporting students in mastering predefined science skills through the development of supports and scaffolds. This led the team to develop and implement numerous linguistic scaffolds to help their multilingual students “become scientists.” Towards this end, examples of emergent language from the team used to describe student mastery were focused on the development of “hard scaffolds” or “structuring everything appropriately, so they [student] gain the vocab as we’re doing activities.”

Fundamental to this shift was that the language the team used in both events provided a window into the decision-making processes they employed to rationalize their reasoning. While at a superficial level the disappearance of the language of “mastery” and the emergence of “awareness” and “action” marked a stark contrast, this offered deeper insight into the ideological shifts that undergirded those decisions. As will be seen in the next section, these pedagogical responsibilities held the key to understanding the deviations in the Living Earth team’s receptivity to adopting the decision-making processes presented during the partnership project.

Pattern #2: With Greater Alignment in Responsibility, a Higher Likelihood of Taking Up the Pedagogical Reasoning Emerged

Between the first and second years of the partnership project, a notable difference emerged in the frequency with which the Living Earth team adopted the presented pedagogical reasoning language from the whole-group setting. Of the 28 events identified in the first year, 14 occurred in the first six months. Among these 14 events, there were only two salient instances in which a transfer in the presented pedagogical reasoning emerged between the whole-group

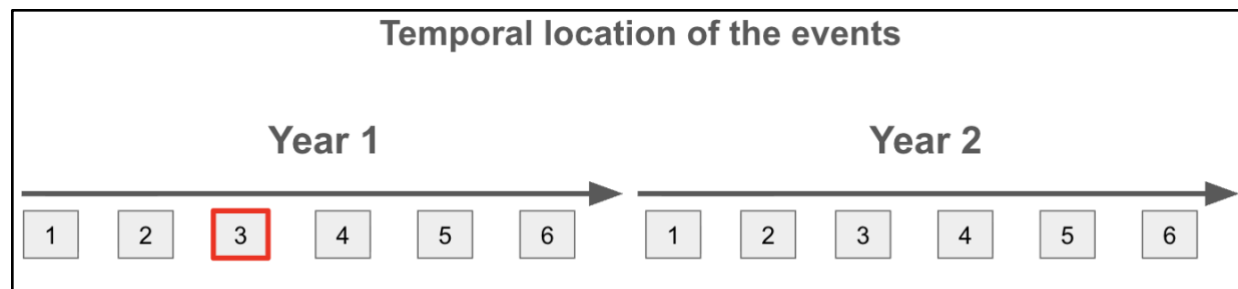
setting and the Living Earth team's subsequent sensemaking conversations. Comparatively, when analyzing the 24 events that emerged during the transitory period, between the end of the first and the start of the second, five distinct but interconnected instances of transfer between the whole-group setting and the Living Earth team emerged. The data analysis revealed that the likelihood of the Living Earth team adopting the shared pedagogical reasoning from the whole group setting during professional learning experiences was far lower at the start of the partnership than during the transitory period, almost nine months later. These variations in the team's uptake of the shared pedagogical decision-making prompted further analysis.

Compared with the beginning of the first year, what stood out at the end was the degree of ideological alignment among the Living Earth team members and collectively with the facilitator or presenting teachers. At the start of the partnership project, the Living Earth team often centralized its pedagogical reasoning around developing supports and scaffolds for students from multilingual backgrounds. This conceptualization of equity, or what the team initially held as fundamental to good and just teaching, foregrounded increasing access and opportunities for all learners (NASEM, 2022). In contrast, within the whole group PD learning experiences, the facilitators regularly drew on the language of "supporting student awareness" and explicitly attended to "student sensemaking." Their conceptualizations of equity foregrounded the expansion of knowledge, re-centering science knowledge around students' own cultural and linguistic backgrounds. From this conceptualization, equity was viewed as a form of disruption that moves science away from a solely standards-based approach (NASEM, 2022). Contextually, these differences were expected, especially given the teachers' diverse backgrounds, with both James and Patty teaching multilingual classrooms and being trained in translanguageing. However, these discrepancies in initial conceptualizations or in pedagogical responsibility

between the facilitator and the Living Earth team shed light on how a shared pedagogical reasoning rationalized by different responsibilities resulted in a murky transfer process (see Figure 10).

Figure 10

Instance #1: Initial Differences in Responsibility Highlighted Murky Transfer Processes



At the start of the first year of the partnership, the facilitators scheduled individual Zoom meetings with each content team to support them in developing their unit’s focus, driving questions, and capstone project (summative project). It was within this meeting that the first instance of transfer emerged between the facilitator and the Living Earth team. However, as will be seen, unlike in the adoption processes that took place months to almost a year later, the team’s adoption of the presented reasoning was not always shared, leading to emerging differences in responsibility, as seen in Part B.

In this meeting, differences in ideology or pedagogical responsibilities among team members and with the facilitator led to a murky transfer of pedagogical reasoning. Here, the facilitator often posed questions or provided input. When she did, the language she used frequently referenced “scaffolds and supports,” with her rationalization grounded in supporting “students’ abilities to make sense of local problems around them.” Conversely, members of the Living Earth team responded to her inquiries or questions with a focus on deepening the unit’s alignment with the NGSS. Specifically, Patty and Samantha discussed the engineering standards

they were attempting to align with as they developed their essential question. The focus by Patty and Samantha was on students' abilities to demonstrate mastery of engineering-based skills rooted in the standards, while the facilitator attempted to push them beyond the defined knowledge and skills.

4:02 Patty: So that is every point across districts, and so even though we are all teaching at different sites, we wanted to make sure we are honoring our scope and sequence, and especially since Nina and I swap back and forth with kids all the time, so it is just beneficial for us to look at that. That was our point for where do we want to start, how long do we want to take this? And then from there we built out.

4:35 Facilitator: So then do you agree, do you feel comfortable to say that addressing all of these DCI, we are going to group it? Addressing all of them is our goal for the six weeks... Because it seems to me the later three are more engineering focused.

4:46 Patty: Maybe not ETS1A because I need to look further into that one... I don't understand that, umm...

4:55 Samantha: Well, I think that A and C would be the ones that we kind of take out. B, though, I think if we are having them look into the future, that would be possible solutions, right?

5:07 Patty: Wait, you have a point. Optimizing the design solution, yeah, they have to first have a solution to then optimize it, so we can eliminate those two.

5:18 Facilitator: You know, in order to think about the solution, they have to define the problem.

5:26 Patty: Mhmm.

5:27 Facilitator: And then the problem that we tried to draw upon is the land use, some problem associated with the land use... and I also see that biodiversity and humans and adaptation and ecosystem, right?

During this event, the facilitator attempted to reframe the team's decision-making to make salient the problem students were trying to address through their unit's design, rather than ensuring that the unit linguistically aligned with the NGSS, and specifically the engineering standards. Patty and Samantha continued to argue that ensuring alignment required the facilitator to make a contrasting decision to focus on the problem. Here, the facilitator was making salient that her responsibility in creating a unit was not to align it with the mastery-based standards, but

rather to support students' sensemaking of the real-world problems they were facing. This marked an ideological difference between the focus of her decision-making and that of Patty and Samantha in this specific moment. Notably, this deviation remained unresolved; moments later, the team stated that they would need to analyze the standards further and determine which were most applicable to the unit. In other words, the team had not adopted the facilitator's pedagogical decision to focus more on the problem than on the standards. This was an ideological difference that was not resolved in this moment.

At that time, Patty and Samantha's pedagogical responsibility was to support students' abilities to master the skills and knowledge outlined by the NGSS. This was a dominant ideological stance established within teacher education programs and the majority of professional training and curricula. In large part, this was due to the demanding nature of state testing and teachers' responsibility to support students' performance. As such, the embedded nature of this ideology undergirded teachers' moment-to-moment decision-making, grounding every choice they made when developing a unit. However, in contrast, the facilitator was responsible for supporting students' ability to sensemake through the problems they and their communities faced every day. This did not mean that Patty or Samantha did not also hold these ideologies. Still, when initially developing the unit's overall design, they foregrounded mastery of standards rather than the facilitator's focus on sensemaking relevant problems.

This was further evident in Patty's response to the facilitator, in which she emphasized the importance of a clearly defined problem. Here, Patty and Nina explained that defining the problem was their focus for the first part of the unit. They went on to explain how they wanted to illuminate differences in land use and biodiversity, bringing in examples from different countries

and discussing the import and export of invasive species that affected land use and overall biodiversity.

Patty: That totally plays into the first wave of our plan, which is like, prior, current, and future, and in our prior histories, the diversity of the land was different, like the swamp in Apple County. How we have utilized various types of plants and how we've introduced invasive species has affected biodiversity. Nina, I am talking for you, but I remember these were your notes. Do you want to take over?

Nina: As far as looking at invasive species, a lot of the species that are in California are found in Australia because of the latitude; they are far south as we are north. So, what is happening when invasive species are introduced is that, even though the plants do well, the animals do not.

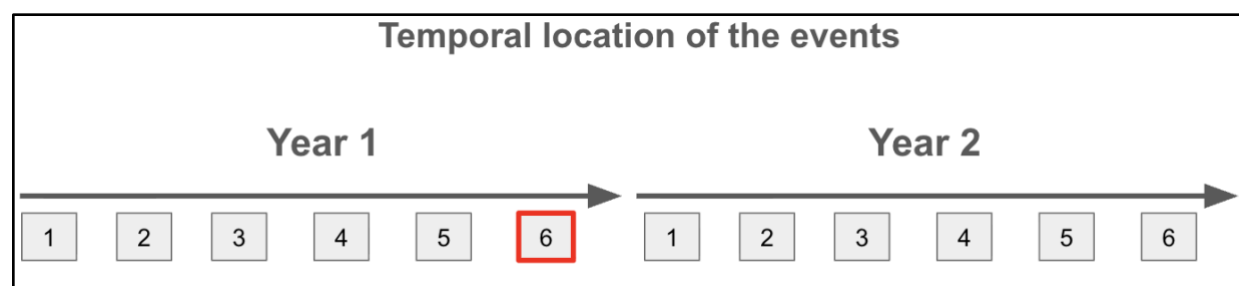
In response to the facilitator's focus on supporting students' sensemaking of problems rather than on standards alignment, Patty and Nina followed up by explaining that they initially wanted to focus on prior, current, and future land use. The focus of their decision-making was on supporting students' understanding of the issues related to biodiversity and how land use had impacted them, with a holistic emphasis on climate change. Although a transfer emerged in this event, it was not clear at first glance; rather, Patty and Nina's response to the facilitator was almost immediate, suggesting that the team had already incorporated that thinking into the unit's design. Here, they went into the numerous phenomena that students could analyze, rather than the impacts that the problems were having on students' lived experiences or the actions they could take against them. Simply, the team's decision-making focused on a phenomenon-based understanding (standards-based knowledge and skill acquisition), rather than on equity-driven awareness or action responsibility. Again, this was not to say that the team did not hold these responsibilities, but at that moment, the ideologies foregrounded were those focused on students' mastery of standards-based scientific knowledge.

When contrasting these divergent responsibilities, it was apparent that the facilitator was working from an ideological stance that prioritized problems and equity over mastery of

standards-based scientific knowledge. This gap between the facilitator and the team highlighted differences in what each foregrounded in making pedagogical decisions. These differences resulted in a messy transfer process between the facilitator and the Living Earth team, as they operated with different foci when defining what constituted good and just teaching. Notably, when these responsibilities were better aligned, the transfer process between the facilitator and the team was much cleaner and more frequent, as seen in the next event, which took place months later, at the end of the first year (see Figure 11).

Figure 11

Instance #2: A Concerted Alignment of Responsibilities Yielded Far Greater Transfer of Pedagogical Reasoning



At the end of the first year of the partnership, after implementing the co-design unit in their classrooms, teachers returned for the final PD of the year. Here, they were tasked with reflecting on the enactment of their units and outlining points of revision and refinement for the second year. Teachers presented firsthand reflections. In addition, they watched selected clips from teaching videos highlighting instructional practices associated with equitable and just science instruction, which had been chosen by the facilitators. It was during these reflectively focused PD learning experiences that the Living Earth team collectively acknowledged their struggles with the enactment of this unit. Importantly, this shared perception that there existed a gap between their intentions, or ideologies, and the actual enactment of the unit was what grounded the transfer process moving forward.

This awareness of gaps between the team's intention and enactment first emerged at the individual level when they shared their presentations. Across all four Living Earth teachers, each explicitly rationalized an action they presented to the whole group, citing the need to deviate from their unit's intended outcome. The rationalization for this deviation was not the same, but each member made explicit mention of an action that was rationalized because of the need for deviation. Importantly, they did not explicitly state why the team felt the need to acknowledge this, but before their shareout, the Chemistry team's members had shared their "stories of implementation." Although they were not entirely unified in their reasoning (with differing reasons emerging, which was expected), some prominent overlapping reasons and actions connoted high levels of alignment not only among themselves, but between their enactment and the unit's intended outcome. Here, David, Emma, and Anya all used the same pedagogical approach in the student public service announcements (PSA) and a soil activity, engaging local farmers to analyze soil quality and discuss farming practices. While each teacher offered distinct rationalizations, a prominent rationale for increasing students' engagement in science emerged across all of their presentations. Most notably, their language illustrated a unified reasoning where they equated the importance of students' mastery of pre-established science knowledge and skills with their role as community activists. The Chemistry team's collective reasoning foregrounded students' relationships with localized injustice and its connection to science knowledge and skills.

In comparison to the Chemistry team's perceived high levels of alignment and the facilitator's earlier explicit use of struggling as a form of rationalization during the PD, the sudden emergence of struggling as a pedagogical reasoning highlighted the role of transfer within their collective sense-making process. For Patty, Samantha, and Nina, this rationalization

of struggle emerged as a lack of achieving the unit's intended outcome. Patty explained that she felt like she had struggled to keep with the "throughline" of the unit, and Samantha shared a similar sentiment. Shortly thereafter, Nina explained that she felt unable to keep up with the rest of the team, highlighting that she was behind and unable to fully implement all planned pedagogical actions within the unit's design. When considering the language presented here and the team's subsequent conversation about "making it matter," the pedagogical reasoning of struggle that emerged in these instances could be seen as a transfer of rationalization between the whole-group and small-group settings. Through their collective comparison of reasoning with the Chemistry team or explicit attention to the struggles all teachers had with enactment, the team's emergence of this reasoning was prompted by the context surrounding it. The emergence of this language resulted from their reflection and subsequent focus on refining elements of the unit's design. Importantly, this language of struggling to enact did not appear only in the team's collective language but was initiated by the facilitators in the whole-group setting.

Later in the PD, the facilitator acknowledged the struggles teachers were having with implementing this work; she presented them with data from a survey administered to each participating teacher's students. Across that data, 60% of students stated that these science units mattered to them, with 70% saying they saw how they connected to the bigger picture. On the other hand, 40% of students stated that they felt their voice mattered throughout the unit. It was at this point that the facilitator acknowledged the fantastic work and the positive takeaways that the students achieved with the unit, while simultaneously drawing teachers' attention to the complexity and importance of refining this enactment. Furthermore, she highlighted some of the challenges the research team observed when visiting participating teachers' classrooms: "we noticed that comparing to the other component like civic engagement component is pretty strong.

We saw a lot of evidence, but when it comes to address injustice, inequity, we find relatively little evidence comparing to the other pieces.” Importantly, the facilitator’s reasoning within this given event called teachers’ attention to the explicit struggle they had in addressing “injustice” and “inequity.” Her differentiation of “addressing injustice” and “civic engagement” provided teachers with salient feedback that illuminated their own gaps in pedagogical judgment.

The linguistic distinction between “civic engagement” and “addressing injustice” highlighted the Living Earth team’s decision to take up the presented pedagogical reasoning to support their own sensemaking during the unit development process. Here, after the facilitator explained the student survey data and her own rationale for the struggles teachers faced when addressing injustices, the teams returned to small groups to reflect on their unit’s initial design. Samantha discussed some challenges she faced, suggesting the need to “[tie] it a little bit more into making it matter, like why do they need to know?” Corroborating her sentiment, Nina elaborated that she did not know if they had factored that in when they had developed the unit. Samantha said, “I know when we talked about that part 1, when we got to the part where the two [indigenous community] met the Spaniards.” Interestingly, Patty pushed back, saying she thought the unit did make a difference for students because she heard them using terms like “equity” and “colonization” in her classroom. While individual members’ rationalizations of that struggle differed, its emergence highlighted the use of new pedagogical reasoning language by multiple members of the team.

Samantha’s decision to address the unit’s ability to “make it matter” to students conceptually drew upon the facilitator’s rationalization of “addressing injustice” as a point of struggle. On the surface, “making it matter” and “addressing injustice” were not similar linguistic terminology, but, from a contextualized lens, Samantha’s “making it matter” language

explicitly built on the facilitator's presented pedagogical reasoning noting that the teachers had struggled to address injustice. As Samantha continued to elaborate on her statement, her focus was not on how the unit mattered to students but on how the colonialization of indigenous communities was written about in history books. Critically, Samantha's conceptualization drew upon the facilitator's previously presented pedagogical reasoning to rationalize her own struggles and determine what needed to change in the unit's future design. Notably, before these two events, Samantha and Nina, along with the team, had never used language associated with struggling to address justice as a rationalization for any of their decision-making processes. This implied that the emergence of this new language, and when contextually embedded, stemmed from their participation in the reflective learning experiences with the Chemistry team and facilitator.

Furthermore, the sustainment of this adopted pedagogical reasoning language was seen months later, at the start of Year 2 (in Part B, Shift #1/Year 2), when Samantha and Patty explicitly reflected on the unit's "dying off." This implied that the adoption of this pedagogical decision-making went far beyond superficial language usage; instead, it highlighted a longitudinal ideological shift that the team held onto far beyond this singular moment. While the team still shared a responsibility to support students' mastery of standards-based scientific knowledge, the peripheralization of this commitment began to emerge when the team acknowledged the struggles they had had with enactment. In the face of these compounding events, the team adopted this rationalization of struggle to recognize gaps in their decision-making processes and refine the unit's design. Months later, they elaborated on it to inform the subsequent shift in focus, moving away from foregrounding standards-based mastery to supporting students in becoming "aware" and taking "action" against localized injustices and

land stewardship. Core to this longitudinal shift was the adoption process between the facilitator or presenting teachers and the Living Earth team.

This transfer of pedagogical reasoning between the facilitator or presenting teachers and the Living Earth team relied on the degree to which the team's collective responsibility aligned both internally across team members and externally with the individuals' presenting. At the beginning of the partnership, the individual team members were operating from different responsibilities, which made collectively rationalizing the focus of their unit more challenging. Compounded with the misalignment between these responsibilities and those of the facilitators, the transfer process of pedagogical decision-making was naturally very messy. However, when the team became aware of the gap between the intended outcome of their unit and its actual implementation, they reached consensus that they had "struggled" to implement it. This sharedness in reasoning-based language highlighted a far more complex ideological shift where the team recognized the importance of equity and justice over mastery of standards-based science skills. Notably, this pedagogical responsibility was what the facilitator had been continually sharing throughout the year through the decision-making language she had used.

When the team not only enacted the unit in their classrooms but also reflected on the gaps between their intentions and actions, they began to work from a shared responsibility, both internally and externally. In other words, the enactment of the unit provided them with first-hand experience in doing this equitable and just work. In contrast, the immediate reflective professional learning experiences that followed allowed them to build their awareness. Once the team had aligned with each other and the facilitators, the transfer of decision-making language between the facilitators or presenting teachers became far more frequent. As such, the criticality

of this shared responsibility, both among the individual team members and between them and the facilitators, was necessary for the transfer process to occur.

Chapter 6: Discussion

Motivated by the critical need to progress the field's understanding of science teachers' collective long-term sensemaking processes of equity, justice, and civic engagement, this study sought to provide further understanding of the longitudinal sensemaking processes of science teachers as they engaged in professional learning experiences focused on equity, justice, and civic engagement. While numerous research studies have illuminated the role that differing professional learning activities play in shaping teacher discourse, perceptions, understanding, noticing, and planned action (Hall, 1996; Horn & Garner, 2022; Philip, 2011; Picower, 2011), the field's knowledge of the long-term sense-making processes teachers engage in as a result of these activities is still emerging (Daniel et al., 2023). The complexity of these sensemaking processes is further compounded by the sociopolitical nature of equity- and justice-based work, in which teachers are not only contending with what they consider good teaching but also with how those ideologies are rooted in White Eurocentric forms of education (Bang et al., 2013; Warren et al., 2020). As a result, when analyzing teacher learning for equitable and just science education, solely studying the enactment of practices associated with these ideologies may not provide a comprehensive understanding of the decision-making processes behind those actions (Horn & Garner, 2022). Especially in the current political environment, accounting for the complexity of these ideological stances and their role in teachers' decision-making processes is critical for future research.

The findings of this study identified three patterns that offer insights into the complex process of teachers' sensemaking and the enactment of justice-centered science instruction. Below, I have made three claims based on the emerging themes and patterns. They are: (1) there is a need to support pedagogical decision-making, instead of teaching practices; (2) it is

important to support teachers as a collective in order to align their ideologies; and (3) it is critical to support ongoing, cumulative interactions to foster transformative change. Each of these either highlights the longitudinal sensemaking processes teachers engaged in when collaborating or illuminates the relationship between the semiotic resources presented within the PD setting and subsequent language used by the Living Earth team. In the discussion section below, I elaborate further on these three claims and how they emerged within the findings.

Supporting Pedagogical Decision-Making Instead of Teaching Practices

The analysis of longitudinal interactions revealed a consistent finding: starting from the period when the Living Earth team experienced the most significant shift in their decision-making language (at the end of the first year and the beginning of the second year), they frequently adopted language from the whole-group setting. This was evident in two of the examples presented in Part C, where the team drew on the pedagogical reasoning language of “struggling” when reflecting on and beginning to revise the unit’s design. Notably, this language was explicitly used by the facilitator previously when exploring student data and again when she rationalized the need to modify the unit’s design. Similarly, in the first PD of the second year (months later), the team explicitly drew upon the language David used to explain the Chemistry team’s next steps, with a focus on “awareness” and “action.” This revealed that during the period when the most prominent shifts in the team’s pedagogical reasoning language emerged, they explicitly drew on the whole-group setting to inform their decision-making.

Simultaneously, when the team drew on the shared decision-making language from the facilitator or presenting teachers, they rarely adopted the pedagogical actions associated with those decisions. For example, during David’s presentation, the pedagogical reasoning he shared focused on supporting students’ “awareness” and “action” through the capstone projects.

Specifically, the Chemistry team had the students develop presentations focused on farming practices. In the Living Earth team's subsequent sensemaking conversation, they drew heavily on David's shared pedagogical decision-making language to support students' "awareness" and "action" (as seen in Parts B and C of the Findings section). However, their reasoning focused on the unit's driving question and the historical reading, not the capstone project. Notably, this was not an isolated event but rather emerged quite frequently.

Together, this meant that teachers were far more likely to adopt decision-making language than the actions it was associated with during a transfer process. More importantly, it suggested that teacher-focused PD needs to explicitly attend to the salience of the decision-making processes that undergird each pedagogical action (Daniel et al., 2023; Horn & Garner, 2022). To this end, teachers have historically been positioned as passive recipients of curricula in PD settings; pedagogical plans and activities are often given to them without the rationale for those decisions being made apparent (Miller et al., 2023). The result of this disconnect can be seen in the past and present challenges teachers encounter while attempting to enact equitable and just science instruction in their classrooms (Braaten & Sheth, 2017; Morales-Doyle, 2017; Tzou et al., 2021). When PD prioritizes the salience of pedagogical actions but not the decision-making processes that rationalize them, teachers are unlikely to adopt these equitable and just pedagogies.

While the salience of pedagogical reasoning emerged as a critical element for transfer to occur, it was one of many needed. The data from this study highlighted that even when pedagogical reasoning was made salient by the facilitators and presenting teachers, the successful adoption of pedagogical reasoning relied on the alignment of collective ideologies both within the team and with the facilitator.

Fostering Teachers as a Collective to Align Ideologies

Further analysis of the longitudinal interactions indicated that the transfer of pedagogical reasoning from facilitators or presenting teachers during professional learning experiences was not always consistent. As previously noted (in Part C), the adoption was quite different between the beginning and end of the first year. At the beginning of the partnership, the Living Earth team was far less likely to adopt the shared pedagogical decision-making language used by the facilitators and presenting teachers than at the end of the year. This was particularly evident in the example presented in Part C, Instance #1 (beginning of Year 1), when the team was working with the facilitator to identify the scope and sequence of the unit. Here, the team initially resisted the facilitator's shared pedagogical reasoning, often attempting to refute her rationale, particularly when Patty sought to leverage other members' experiences as evidence. In contrast, at the end of the first year and the start of the second, the team collectively drew upon the shared decision-making language of "struggling," "awareness," and "action" to inform their collective choices.

Emerging from these differences was the degree of alignment in pedagogical responsibility between the Living Earth team members and with the facilitator or presenting teacher(s). In other words, when the team was collectively operating from ideologies that did not align with each other or with the facilitator, they were far less likely to adopt the pedagogical decision-making language. This was particularly evident when comparing Instances #1 and #2 in Part C. When the Living Earth team members were ideologically foregrounding varying principles of equity, with Patty and Samantha highlighting standards alignment, Nina attending to indigenous history, and James focusing on multilingual learner support, the team was operating from differing responsibilities. In addition, the facilitator's ideological focus was on

student sensemaking and on the unit foregrounding the localized problem, rather than on standards alignment. These opposing ideologies led to a collective misalignment, leaving the team struggling to maintain a concerted focus. Comparatively, at the end of Year 1 and start of Year 2, the team had a far more aligned equity responsibility rooted in their shared commitment and recognition that the unit had initially struggled to address its full intentionality.

Stemming from the collective alignment that they had “struggled” to enact the unit, and emphasizing the “dying off” of the unit’s social justice elements, the team took on a shared responsibility to foreground civic engagement in their revised unit design. The sharedness of this responsibility emerged from the multi-stage learning experiences that occurred at the end of the first year and through the start of the second. Here, the team not only enacted the unit they had designed but also observed other teams’ reflections on enactment, analyzed student experience data, and reflected on key aspects of their unit’s design. Notably, no single activity emerged as the key event that yielded this shift; it was the culmination of these compounding experiences that resulted in the discursive changes and receptivity to adopting presented reasonings. What started as a reflective point from Samantha, who wanted the unit to “matter” more to students, turned into a collective understanding that the unit had “died off” and needed to be revised to address this.

Here, I explicitly do not want to highlight specific activities or learning experiences that were the critical element in shifting the team’s collective reasoning, as this would shift the focus away from the longitudinal and substratic nature of this work, but it is important to recognize a learning experience that took place between the first and second year. Patty, one of the initial members of the team, participated in a teacher–researcher experience over the summer, during which she engaged with researchers who further analyzed the Living Earth team’s data.

Importantly, through her participation in this experience, her perception of the unit's issues aligned with Samantha's initial reflection, and she sided with Samantha's view that the social justice aspect of the unit did not meet its intended purpose. When the team returned for the second year, there was now a shared reasoning that the unit's social justice element had "died off" and needed to be fixed. With Patty now onboard with the rest of the team, a unified focus on revising the unit and explicitly attending to social justice emerged.

Collectively, the team was operating from a shared rationale to refine the unit, but undergirding this decision was the renewed responsibility to shift the unit's design away from standards-based science understanding toward foregrounding civic engagement. As a result, at the beginning of the second year, the team was operating under a shared responsibility that not only governed their decision-making but that also led to the greater adoption of shared pedagogical reasoning in subsequent learning experiences. This was evident in how prominently the transfer of reasoning focused on developing students' "awareness" and "action" in social justice, as taken from David's presentation. Without the team's collective responsibility, the adoption of pedagogical reasoning would not have occurred at the frequency it did during the second year.

Supporting Ongoing, Cumulative Interactions to Foster Transformative Change

To this end, while David's presentation could be viewed as a subversive or transformative event, the Living Earth team's subsequent language immediately changed, building on over a year's worth of established conceptualization. During the first year, the team's language regularly emphasized the importance of developing supports and scaffolds to help students master predefined science knowledge, thereby strengthening their scientific understanding. Yet, in the second year, this language of mastery seemingly disappeared, with a

concerted focus on supporting students’ “awareness” and “action” regarding localized injustices. While the team did use equity-based language during the first year, this language centralized the pedagogical reasoning behind developing supports and scaffolds for multilingual learners. Simultaneously, there was a shift in language within the whole group space, where facilitators and teachers centralized the focus on “awareness” and “action” for civic engagement, rather than the prior language of “expanding what counts as science.” The shift in language the Living Earth team underwent paralleled the linguistic change across the whole group.

Significantly, understanding this parallel extended beyond mere language mirroring to an accumulation of language that resulted in a transformation for all subsequent interactions. Goodwin (2018) highlighted the phenomenon through his use of *substrates*, in which a given moment-to-moment interaction results in a change or evolution in the language used. However, while a substratic or transformative event results in a subsequent shift in language use, the accumulation of language within its context provides critical information for understanding the potential reason for the change. Goodwin (2018) highlighted this accumulation through the case of Chil, a man with aphasia who had a lexicon of only three words. Chil’s interactions over time, through patterns of speech with his family and friends, allowed these three words to convey an understanding beyond their intended meanings. While Chil’s lexicon shifted, the intentionality of the language he used built on prior interactions and allowed him to convey meaning to those around him, despite the language’s transformation. Now, while not quite the same, the shift from “expanding what counts as science” to “awareness” and “action” for civic engagement highlighted a similar change of understanding.

In the first year of the partnership project, when the terminology of “expanding what counts as science” was centralized, the Living Earth team also continued to foreground students’

mastery of predefined science skills to become scientists. Importantly, these were teachers who were deeply committed to equitable and just science teaching, so their continued use of this language implied an ideological conceptualization of expanding involvement, support, and scaffolding. In their initial interviews, when asked to define what good teaching was, they prominently focused on the need for support and scaffolding for all students, with Patty and James explicitly attending to multilingual learners. Furthermore, even when the presenter expressly limited this conceptualization at the end of the year, the team continued to draw on the language of mastery to rationalize future refinement. It was not until the explicit and continued use of “awareness” and “action” that a collective and sustained shift occurred among the Living Earth team. Specifically, this shift occurred in both settings after David’s presentation on the Chemistry team’s capstone projects and student sensemaking as being rooted in these conceptualizations.

When this longitudinal linguistic transformation was compounded with the team’s collective alignment in pedagogical responsibility, the catalytic nature of David’s presentation emerged. Prior to this event the team had collectively aligned on their responsibilities to revise the unit, along with the accumulation of language towards civic engagement-building within the whole-group PD setting, the result of which was a prominent and sudden shift in the team’s pedagogical reasoning language. As such, noting the power and impact such professional learning experiences have on teachers’ subsequent actions, reasoning, and responsibilities, it becomes imperative to study their longitudinal design.

Chapter 7: Implications & Conclusion

The longitudinal analysis of this study revealed the deeply complex and multi-faceted nature of teacher sensemaking as they co-developed an equity, justice, and civic-centered unit through a two-year partnership project. Here, multiple analytic frameworks were used to capture the complex shifts in discourse and practice, revealing both individual and collective ideological changes in how they define and enact these constructs in their classrooms. While prior research has conducted similar analyses (Daniel et al., 2023; Penuel et al., 2012), their focus has been on short-term sensemaking processes within the professional development setting (Crabtree & Stephan, 2023; Damjanovic & Ward, 2023; Gargroetzi et al., 2021; Picower, 2011). It was in these calls (Horn & Garner, 2022; Russ & Luna, 2013) that this study expanded upon prior research to explore teachers' longitudinal sensemaking processes as part of a 2-year professional development project. From this analysis, multiple implications emerge regarding the structure and analysis of teachers' collective learning in equity, justice, and civic engagement.

Firstly, one-off PD or short-term learning experiences focused on teacher learning are less effective at supporting shifts in teachers' understanding (Penuel et al., 2020). Changes in pedagogical action are a direct result of ideological shifts in what teachers consider good and just teaching (Horn & Garner, 2022; Russ & Luna, 2013). As seen in the findings, evolution in pedagogical actions did not arise solely from modeling best practices; it resulted from long-term sensemaking conversations among peers in these professional learning spaces (Bancroft & Nyirenda, 2020). For this reason, when PD learning experiences focus on supporting equity, justice, and civic engagement, administrators, facilitators, and researchers must make salient the teachers' ideologies that govern their decision-making processes. The observed changes in the Living Earth team's pedagogical actions, reasoning, and responsibilities were not mere

happenstance but the result of strategically timed learning experiences designed to address each of these constructs.

The longitudinal design of the partnership project afforded teachers numerous opportunities to emerge and navigate their ideologies of what they held as good and just teaching. Here, the team authentically learned about, enacted, reflected on, and refined equitable and just instructional practices through the collaborative design process of their units. However, it was not until after the team enacted and subsequently reflected on their unit that a transfer emerged between the whole-group learning setting and their own sensemaking processes. By strategically using reflective activities, such as analyzing the student experience survey, teams identified gaps between their intentions and their enactment. At this point in the sensemaking process, the team began to draw more frequently on the shared reasoning presented by the facilitators in the whole-group setting. Even then, it would not be until months later that the team would adopt decision-making language more frequently from the whole-group setting.

The increased frequency in their adoption of shared pedagogical reasoning stemmed from the alignment in their responsibilities, both amongst themselves and with the facilitators who were sharing their pedagogical reasoning. As seen in the findings, the adoption of pedagogical reasoning required the team to be operating from a shared commitment; they would be constantly attempting to override each other's decisions. Additionally, their responsibilities needed to align with the presenting teachers and facilitators. This was primarily due to the complex, continually evolving nature of equity and justice, as there is no universally defined, shared understanding of these terms (Philip & Azevedo, 2017). As seen in the NASEM (2024) report and in other educational studies (e.g., Kang & Nation, 2023; Morales-Doyle, 2017; Philip & Azevedo, 2017), the concepts of equity and justice are conceptualized for different purposes. For example, equity

work focuses on developing supports and scaffolds (Level 1) versus addressing the heterogeneity of science knowledge (Level 3) (NASEM, 2024). As such, when facilitators shared their own pedagogical responsibilities for “expanding what counts as science,” the team initially interpreted this as additional supports and scaffolding. Not as foregrounding civic-centered instruction over standards-based mastery. This deviation in conceptualization may have played a critical role in the lack of adoption in pedagogical reasoning that emerged between the team and the whole group setting.

To no one’s surprise, this sensemaking process was messy, complex, and required significant time to yield learning at both the collective and individual levels. While research has shown that PD with a focus on equity and justice can result in teacher learning (Sleeter, 2017), and that strategic activities are fundamental to that process (Adah Miller et al., 2023; Crabtree & Stephan, 2023; Damjanovic & Ward, 2023; Gargroetzi et al., 2021; Picower, 2011), this sensemaking process involved relational (Horn, 2007) and temporal factors (Daniel et al., 2023) that were core components of these shifts. When constructing learning experiences for in-service teachers, each of these factors needs to be considered and accounted for by facilitators, administrators, and researchers to support teachers in the sensemaking process of equity, justice, and civic engagement.

Conclusion

Given the rampant attacks on equity- and justice-based work, there is an ongoing need to understand and support teachers as they engage in longitudinal sensemaking processes focused on creating disruptive spaces. With PD being a primary mechanism for supporting teacher learning (currently), such trainings must expand beyond simple one-off models and shift towards long-term, focused endeavors. In these spaces, teachers must be allowed to make visible not only

the practices they employ but the decision-making processes and ideologies that rationalize them. To this end, it is critical that these spaces not only engage teachers where they are in terms of their own responsibilities for what is good and just teaching, but that they also recognize the interconnectedness of people and ideas.

While individual teachers can enter these settings already deeply committed to this work, as seen with the Living Earth team at the start of the partnership, that does not automatically ensure that a civic-centered product will be produced. Professional development designed around the deployment of curriculum or shifts in teachers' practices cannot solely attend to actions; it must ground its modeling and presentations in the pedagogical reasoning and responsibilities that rationalize them. As seen in the data, teachers within the Living Earth team did not adopt the specific pedagogical actions presented in the whole-group setting; they drew on the decision-making processes behind those actions. While curriculum is a critical component of teaching, the rationalization behind the actions emerged as a fundamental element for shifting action.

Towards this end, research exploring collective sensemaking processes within PD spaces needs to account for the actions, reasoning, and responsibilities they employ. As such, shifting teachers' practice requires ideological changes in their understanding of what they consider good and just teaching. This process did not immediately happen; instead, it took months, if not years, for the team to consistently adopt decision-making language. However, this adoption of reasoning was followed by the team's increased alignment with the whole-group setting. The more the team aligned with what they considered good and just teaching, the more likely they were to adopt the decision-making processes associated with those ideologies. As such, future research should account for this relationship between ideologies and decision-making processes

to strategically focus on supporting teachers' responsibilities, shifting their reasoning and the subsequent actions they deploy in their classrooms.

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Appendice

Year 1 Unit Story and Explanation

Unit Essential Question: How can we, as stewards of environmental justice, acknowledge the actions of the past to mitigate human impact on climate change for more sustainable Earth ecosystems?

Unit overview

The unit begins by presenting historical images/photos of Apple County. Students will be invited to share stories about their ancestors or people who used to live in this land, and how the land use has changed over time. Then, students will be invited to share their initial thinking in response to the unit's essential question, "How have the various histories of use of our land contributed to the changing climate of Apple County?" [initial assessment]. After learning about students' initial ideas, experiences, and stories, the topic of this unit's project will be presented [capstone project] along with the expectations. Students will be grounded based on their interest (theme-based grouping) to engage in a YPAR project. As a small group, students will explore land use in Apple County focusing on one of the themes or problems: its impact on biodiversity, temperature, precipitation, etc. Students as a small group will complete the milestones as instructed by the capstone project handout throughout the unit. Students will be tasked to design the proposed land-use for a sustainable and thriving future. Near the end of the unit, they will produce an artifact that explains how and why their proposed design will contribute to mitigating climate change. Students also engage in the final assessment that demonstrates any changes or expansion of their thinking throughout the unit.

Year 1 Unit Assessment

Objective: The purpose of this activity is to demonstrate students current knowledge of Apple County historical land usage; Modeling land usage impact on local biodiversity; Apple County's historical climate change in regard to temperature and precipitation.

Driving Question: How have the various histories of use of our land contributed to the changing climate of Apple County?

Part I. Understanding the historical land use in Apple County

- Apple Groves in (redacted)
- Sugar Beet Farms in (redacted)
- Koi Farms in (redacted)
- Cattle Farms in (redacted)
- Farms in (redacted)

From the provided list, select TWO and describe how land use changed over time.

Your choice	Description of how land use changed over time
#1:	
#2:	

How do you think the change of the land use in West (redacted) contributes to the climate change of Apple County? Be sure to use **at least one** of the items from the explanation checklist you're comfortable explaining and **at least one** you would need to conduct additional research on to explain.

- The increase of invasive species or loss of native species
- Increase of hardscape on Southern California (runoff)
- Changing pattern of local and global temperature
- Effect of urban heat island on local temperatures
- Frequency and intensity of droughts
- Changes in local biodiversity
- Changes to observable patterns in weather (rain, drought)

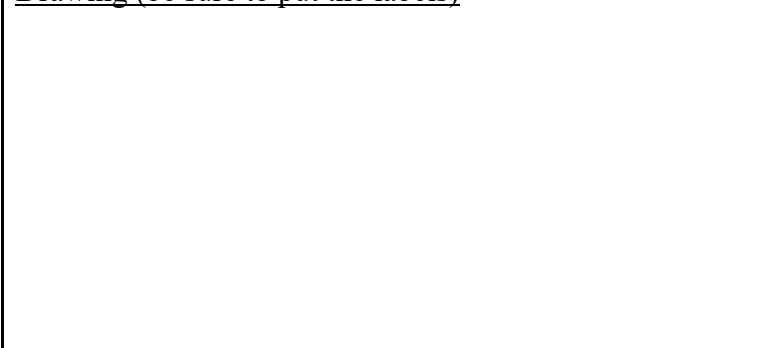
I think this land use contribute to the climate change *because...* _____

The evidence that supports my claims comes from _____. This activity/data/information shows that _____

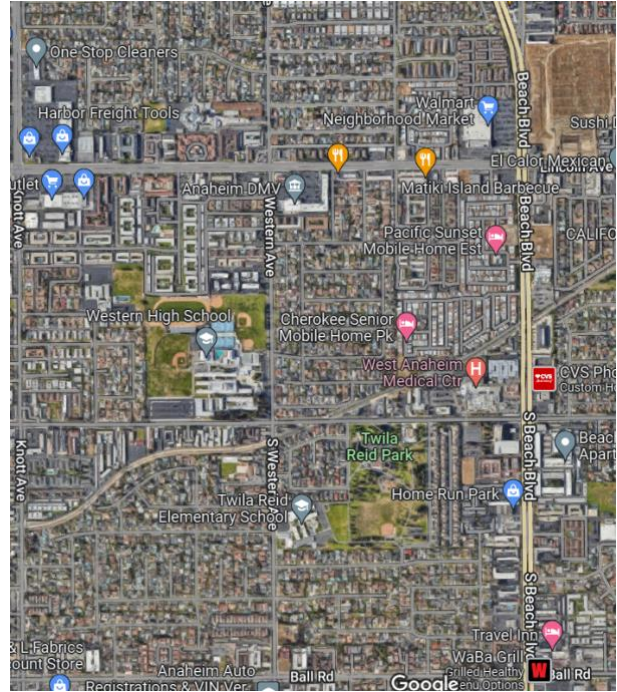
Part II. Designing Our Future

Identify one place that you would like to propose the design of land use

Draw and explain your proposed design of land use

<u>Drawing (be sure to put the labels)</u>	<u>Describe your drawing</u>
	

Explain how this way of using the land will create more sustainable community in the future



1. Instructions: Make a list of at least three differences between West (redacted) today and West (redacted) 68 years ago based on the pictures above or what you already know. (Pictures are also on eKadence so you can view them easier)

1	In 1955 ...	While in 2023...
2	In 1955 ...	While in 2023...
3	In 1955 ...	While in 2023...

2. Do you think the changes of the land use in West (redacted) contribute to the climate change of Apple County?

Yes No

3. How do you think the change of the land use in West (redacted) contributes to the climate change of Apple County?

The major change in land use in West (redacted) between 1955 and now is _____.

I think this change of land use contributes to the climate change because... _____

5. Temperature and Precipitation

Temperature and precipitation are important factors in an area's climate. Based on what you already know about California's current climate, predict what you would expect the climatograms to look like for (redacted) in 1955 and (redacted) in 2023.

This image shows a full page of blank graph paper. The grid consists of small, equal-sized squares formed by thin black lines. There are 20 columns and 20 rows of squares, creating a total of 400 square units. The grid covers the entire area of the page, leaving no margins or additional markings.

Year 2 Unit Story and Explanation

Driving Question: How can we, as stewards of environmental justice, acknowledge the actions of the past to mitigate human impact on climate change for more sustainable Earth ecosystems?

Explanation:

Before colonial times, our land was predominantly used for agricultural and living purposes. The majority of the native ecosystems were still intact and humans lived in harmony with the ecosystems, as stewards of the land. With the influx of immigration, colonialism, and the urbanization of this local community, we acknowledge that land was stolen from the (Indigenous People) and repurposed for large-scale commercial use.

As we look to the present day, we see a significant change in the way land is being developed and undergoing urbanization in Apple County. Society has strategically and indiscriminately developed the more habitable portions of the land, which leads to the destruction of native ecosystems. For example, Japanese families built and developed (redacted) in what is now known as (redacted). Due to the Japanese Internment Camps, imposed after Pearl Harbor during World War II, the city of (redacted) reposessed the farmland. After the brothers passed, Walt (redacted) purchased the land and put up a parking lot. With the population increase, the stress on local resources contributes to the release of significantly more greenhouse gasses into the atmosphere. Historically, resources, such as petroleum, were kept in carbon sinks. Due to the increased demand for fossil fuels, these sinks have been depleted to meet demands. This has dramatically increased carbon emissions and helped increase the impact of greenhouse gasses.

Due to the increase in local temperatures and decrease in average yearly rainfall over the last 50 years, there has been a negative impact on local ecosystems. The increase in temperature can negatively impact a species' survival rate and create an opportunity for invasive species to take over this empty niche. Invasive species are also being introduced through urbanization and historical global imports. This can be seen with the large population of eucalyptus, bottle brush, and other Australian species that were brought in due to similar climates. These impacts decrease the overall biodiversity of local ecosystems and are setting the foundation for local extinctions.

As we look to the future and work to mitigate these mistakes, changes have to be made in ways that are sustainable and return us to being stewards of the land. These changes must be made in collaboration between local (Indigenous People) tribes and communities as their knowledge and history with the land can help us address the issues we have created for ourselves. Changes to land use can begin at a small scale within smaller communities, such as introducing more softscapes planted with native plant species or introducing community gardens. Ultimately, as stewards of environmental justice, we would need to work together to lobby and vote for

legislation that actively promotes and enacts restorative practices that help heal and reinstate local ecosystems into our communities, such as promoting environmentally conscious land development that still meets the needs of the community.

Year 2 Capstone Rubric

Living Earth CAPSTONE PROJECT RUBRIC

	Highly Proficient (4)	Proficient (3)	Nearing Proficiency (2)
Framing the Problem	All of the steps to the specified problem are clearly outlined and explained as it is written down. Students demonstrate significant content knowledge by explaining concepts while explaining results/answers. All topics addressed in the directions are thoroughly explained to show an understanding of how to solve the problem and the assigned problem.	The gist of the information is presented with some details lacking or not explained. The explanation is accurate.	Missing parts of the information. In the students' explanation, the content knowledge is not entirely correct and the solving of the problem is incorrect.
Research	All information presented is accurate and applies directly to the problem being solved.	Some information is misstated, but the big ideas are accurately presented.	Several significant ideas are misstated and inaccurate.
Call to Action	The solution addressing sustainability is precisely stated and described. The sustainability practice is clearly explained as well as why this practice was selected.	The solution addresses sustainability but some aspects of descriptions and explanations are missing.	The solution attempts to address sustainability but information is missing.
Taking Action	Who is the presentation for? Why did you choose this person/group/community/etc? What impact would they have? Will they be able to enact the changes? How do you know you have reached the desired audience?	The presentation is missing 2 of the 5 stated criteria and/or information is not clear.	The presentation is missing 3 of the 5 stated criteria and/or information is not clear.
Justice	Students show their awareness of injustice while expressing their concerns. Students express the positive or negative impact as well as who	Show some awareness, but do not clearly articulate the impact	No evidence/attention

	benefits or is affected accurately. Use the language of fairness.		
Clear, thorough delivery	This could be used to teach someone who does not know the topic. The presentation of information is clear with a logical progression.	The information is presented clearly with some sequencing problems.	Information is mentioned without logical order or connections.
Presentation Design	The presentation is visually appealing and includes graphics, text, and other tools to enhance its ability to explain complex topics.	The presentation has a mix of media, but the choices aren't always the best choices to convey information. More variety could be used.	The presentation is only text; a variety of media were not used to communicate information.

Year 2 Unit Assessment

Objective: The purpose of this activity is to demonstrate students' current knowledge of Apple County's historical land usage and to apply knowledge of changes in land use to local biodiversity and the connection to Social Justice.

Driving Question: *How can we, as stewards of environmental justice, acknowledge the actions of the past to mitigate human impact on biodiversity for more sustainable Earth ecosystems?*

Part I. Understanding the historical land use in Apple County

Choose one from the list below OR use one example you are familiar with.

- | | |
|---|-------------------------------------|
| ☐ (Redacted) | ☐ (Redacted) |
| ☐ (Redacted) | ☐ (Redacted) |
| ☐ (Redacted) | ☐ (Redacted) |
| ☐ Other Example: | |
-

1. How has the change in land use in this region contributed to the change in biodiversity of Orange County?

Be sure to use **at least two** of the items from the checklist box below, citing relevant evidence from our readings, activities, or labs that support your explanation.

- The increase of invasive species or loss of native species
- Increase of hardscape on Southern California (runoff)
- Changing pattern of local and global temperature
- Effect of urban heat island on local temperatures
- Frequency and intensity of droughts
- Changes in local biodiversity
- Changes to observable patterns in weather (rain, drought)

2. This land use contributes to the change of biodiversity

because... _____

3. The evidence that supports my claims comes from _____.

4. This activity/data/information shows that...

Part II. Designing Our Future While Reflecting on Our Past

5. Using the Indigenous people as inspiration, *identify* a place in Apple County that needs a land use redesign.

Location: _____

6. Model: In your land use model, develop the changes that need to be made to create a more sustainable and biodiverse community. Include a minimum of 3 actionable changes. As needed, provide descriptions, labels, and arrows to better visualize your thinking.

Describe changes in land use	Explain how this change impacts on biodiversity & sustainability

#1:	
#2:	
#3:	

Part III: Social Justice

Access to clean air and water, as well as green spaces with trees, are a few examples of Environmental Justice. Ensuring that all members of the community have safe living conditions is also social justice. From the Indigenous people living along the Apple County River to people living in Apple County today, provide a specific example of Social Justice.

7. A social justice issue from this unit is ... _____

8. Using evidence explain who is being harmed and who is benefiting _____

9. Describe how you can contribute to a more equitable future. _____
