

**Exploring Liberatory Possibilities of Anti-Racist and Anti-Colonial Elementary Science
Education across a School District**

Anastasia Sanchez

A dissertation

submitted in partial fulfillment of the

requirements for the degree of

Doctor of Philosophy

University of Washington

2024

Reading Committee:

Phillip Bell, Chair

Emma Groves

Niral Shah

Program Authorized to Offer Degree:

College of Education

©Copyright 2024

Anastasia Sanchez

Abstract

Exploring Liberatory Possibilities of Anti-Racist and Anti-Colonial Elementary Science
Education Across a School District

Anastasia Sanchez

Chair of the Supervisory Committee:

Dr. Phillip Bell

College of Education

Background: This dissertation examines the pervasive influence of the white and colonial imaginary in shaping educational narratives that promote neoliberal success and capitalism, impacting the minds of successive generations. Contemporary youth perceive these narratives as detrimental, contributing to racial violence, climate-induced displacement, and ecological degradation. The growing disillusionment among young people calls for a shift towards cultivating authentic, responsible, and reciprocal narratives prioritizing critical eco-relational significance and fostering sustainable futures (Fowler, 2023; Vamvalis, 2022; Han, 2022; Whyte, 2018). The design research shared in this dissertation not only illuminates the intricate eco-relational brilliance and radical care exhibited by some of our youngest geologists, engineers, scientists, and critically conscious citizens, but it also unveils liberatory trajectories for teacher (un)learning and pedagogical commitments associated with anti-racist and anti-colonial approaches to science education. This work serves as an offering and an

encouragement to embrace boldness, bravery, and a committed rogue approach against racism and coloniality in education.

Methods: The dissertation employs Design-Based Implementation Research (DBIR) (Penuel et al., 2011), guided by social practice theory (Bell et al., 2012; Lave & Wenger, 1991), and an In-relations methodological practice (Tachine & Nicolazzo, 2023) animated by Indigenous eco-critical and critical race theory. The collaborative design research was conducted within a network of elementary school, kindergarten to sixth grade educators across a suburban school district. Educators participated in a 15-month professional development initiative designed in accordance with the Social Focus Framework (Sanchez, 2024) to build capacity for anti-racist and anti-colonial education. This involved a network of teachers participating in critical learning as a collective and in grade-level teams involved in co-designing curriculum and iterative implementation. Ethnographic, artifact-based, and interview data was analyzed through critical ethnographic methods involving participant-observation, interpretive analysis and coding of student and teacher artifacts and teacher interviews, and theory-driven focused coding of student interaction.

Findings: The dissertation is structured into three papers, each addressing different aspects of the research. In Paper 1 (Chapter 2), I document the diverse learning pathways of elementary teachers engaged in anti-racist and anti-colonial education. The findings reveal that teachers' engagement in sensemaking, critical meaning-making and situated actions varied significantly, influenced by dimensions of whiteness such as innocence, ignorance, saviorism, and arrogance. Teachers who adopted a "rogue settler diligence" approach showed significant progress in anti-racist and anti-colonial teaching practices, highlighting the developmental nature of critical teacher learning. In Paper 2 (Chapter 3), I present a case study focused on a second-grade student

who exemplifies the potential for young learners to engage in eco-relational caring practices during a geology unit. The student's end-of-unit presentation underscores the importance of nurturing relational epistemologies (Bang et al., 2018) to support speculative (re)worlding in socio-ecologically precarious times. In Paper 3 (Chapter 4), I follow third-grade students prioritizing multispecies justice, anti-racism, and anti-coloniality in a science unit. The students' development of just worlding engineering design principles illustrates their capacity to envision and advocate for radically caring and sustainable futures.

Contributions: The dissertation offers several design principles for transforming education, as well as fields of science and engineering:

1. **Teacher (Un)Learning Pathways Towards Antiracist and Anticolonial Science**

Education: Analysis of teacher learning pathways highlights the developmental nature of critical teacher learning, emphasizing the need for sustained, reflexive, and rigorous professional development to counter white supremacy and coloniality.

2. **Honoring Kindred Relationality as Design Priority:** Prioritizing relationality in curriculum design fosters radically caring approaches in science and engineering education, aligning with children's inherent eco-relational perspectives.

3. **Critical Liberatory Presencing of Multispecies, LandAirWaterStars, and Rights of Nature:** Integrating diverse ecological perspectives disrupts human supremacy narratives, promoting interdependent thriving.

4. **Transparency and Humility as Valued Design Stance:** Emphasizing transparency and ethical curiosity in scientific inquiry challenges traditional power dynamics, fostering a more inclusive and collaborative scientific community.

- 5. Resistance and Refusal as Valued Design Practice:** Encouraging children's principled resistance and refusal to harmful actions cultivates liberatory learning environments and responsible, ethical STEM education.

Overall, the research highlights the potential of young learners to contribute to a more equitable and sustainable world and offers insights into how district-level initiatives can support such transformative educational practices. This dissertation ultimately affirms the crucial role of education in shaping a just and caring future, guided by the eco-relational brilliance and radical care of young learners. The work shows that this was only possible across a school district through a sustained, coherent, and critical approach to shared teacher learning and support of situated actions related to instructional practice that enacted anti-racist and anti-colonial approaches.

TABLE OF CONTENTS

Dedication & Acknowledgements.....	3
Introduction.....	5
Building Capacity to Educate for a Future Justly Responding to Racial Realism.....	7
Methods: Using Design Based Implementation Research to Build Teacher Capacity for Orchestrating Anti-racist and Anti-colonial Un/Learning.....	10
Research Context & Participants.....	12
Lines of Research.....	14
References.....	17
Chapter 2. Documenting Elementary Teacher (Un)Learning Pathways Towards Antiracist and Anticolonial Science Education Across a District.....	21
Theoretical Foundations.....	23
How Unveiling False Consciousness Can Awaken Critical Settler Consciousness in Teaching and Teacher Education	26
The Framing of Anti-Racism and Anti-Coloniality for Liberatory Teacher Education.....	28
Methods: Infrastructuring and Studying Teacher (Un)Learning Pathways Through Design-Based Implementation Research.....	37
Findings: Documenting Elementary Teacher (Un)Learning Pathways Towards Anti-Racist and Anti-colonial Science Education.....	58
Theoretical Discussion of the Teacher (Un)Learning Pathways.....	87
Conclusions & Implications.....	97
References.....	100

**Chapter 3. Disrupting white Geology in Science Education by Centering the Eco-Relational
Mattering of Consequential Lands: A Second Grade Student Case Study of
Possibility.....120**

Theoretical Foundations: Making Space for the Mattering of Consequential
Concerns..... 123

Methods..... 127

Findings..... 133

Conclusion & Implications: Creating Spaces for Young People to Imagine Critically
Hope-filled Futures for Thriving Lands..... 168

References..... 171

**Chapter 4. Just Worlding Design Principles: Childrens’ Multispecies and Radical Care
Priorities in Science and Engineering Education.....179**

Theoretical Frameworks..... 182

Methods..... 188

Findings..... 195

Discussion: Childrens’ Just Worlding Design Principles..... 205

Implications:(Un)Learning and (Un)(Re)Becoming With and For Children..... 215

Conclusion: Designing Beyond ‘Situation Critical’ towards Kincentric Flourishing.... 217

References..... 219

**Conclusion: Toward a District-Level Multiscalar Approach to Engaging Young People in
Critical Speculative Design..... 225**

Liberatory and Thriving Futures are at Stake..... 225

Elements of an Educational Transformation Framework to Engage Youth in Critical
Speculative Design..... 228

Final Thoughts..... 239

Implications:(Un)Learning and (Un)(Re)Becoming With and For Children..... 240

Appendices..... 244

DEDICATION

This dissertation stands as a tribute, first and foremost, to my remarkable children, Octavio and Joaquin. "I love you too" - WE did it! You are my *raison d'être* and my most diligent teachers. Failure was never an option, fueled by your unwavering, sometimes distracting confidence and pride in me. I sincerely hope that this work contributes to a better world for you and our beloved Mother Earth. Secondly, I dedicate this dissertation as an offering to all my ancestors and family; thank you for the toil, the struggle, the sacrifice, the love, the faith, and the dreaming amidst the monsters of injustice. I am where I am today, blessed with opportunities, because you demanded more.

ACKNOWLEDGEMENTS

To my students, you are my inspiration, the experts. More than any scholars, the experiences and wisdom from students in the classroom before and during my doctoral program. To my esteemed committee, thank you for your grace, guidance, and care. Dr. Niral Shah, your high expectations elevated my thinking and writing. Dr. Emma Elliott your deep connections to sacred knowledge have grounded me. Dr. Clarita Lefthand-Begay, your kind support has been invaluable. Dr. Philip Bell, where to start, you were so much more than an advisor, you were a colleague, a co-conspirator and a trusted rogue *comrade*. Quite honestly your unwavering faith and confidence in me gave me fuel when academia left me empty. Thank you for your commitment to youth, Indigenous resurgence, ecological and social justice, and making your mentees success personal, because it should be personal.

To my ROGUE SETTLERS: Katie Koressel you have been my rock and evidence that

settlers can be fiercely rogue. This research began with deep roots because of our teaching partnership, turned friendship. The Social Focus is because we are!

Kelsie Fowler thank you for always walking me back from the ledge, Capricorn-ing when I lost my way, standing not in front, or behind me but beside with me, being a brilliant thought partner and never letting me doubt my brilliance.

Lashanna Williams, thank you for always reminding me of what is real and what is magic and that I am both. You saw the tears, surrounded me with flowers and pushed me to get this 'ish done.

Olga Mashnitskaya, your huge heart and faith in justice and truth has been a harbor during some very dark storms.

Sarah, Caroline and Chris you stood up for justice and for the Social Focus when you didn't have to and it cost so very much but I thank you and I am so very proud of each of you.

Becky Bronstein, Bethany Kogut, Cam Foy and Cameron Steinback each of you leaned into transformation and climate justice, mind, body and soul (onto-axio-epistemic) in ways that filled my heart with awe, and often my eyes Water, your solidarity and integrity is truly inspiring.

To my rogue Edmonds teachers, this dissertation is because of you and I deeply appreciate being able to learn from you. Stay rogue, stay diligent, and thank you for embodying and enacting liberatory possibility!

To my BIPGM Rogues, thank you for all the edges you are forced to walk and that you do with such radical love, you matter, I see you, I wish you rest and revolution.

And lastly, to myself, I acknowledge my tenacity and courage. Now, may I embody rest, reciprocity, rightful relations, joy, and radical care!

INTRODUCTION

“In white and colonial imaginaries that thrive on the thrill of control and subjugation, we still frame learning as ‘mastery’ – a horrific, horrific imaginary.”

-Pratim Sengupta (2020, p. 1)

For many adults, we have digested and absorbed chapters, upon chapters of the white and colonial imaginary, handing over our pre-colonial minds, piece by piece, grade by grade, to a neoliberal success narrative of capitalism promising us positions as masters over masters. The act of consuming and endorsing the narrative that encourages mastery as a pathway to success has the potential to detrimentally impact successive generations. This narrative, prevalent in educational settings, is perceived by aware youth as nothing more than a disconcerting portrayal—a depiction woven into the fabric of a Westernized dream, reflecting escalating racial violence, oppression fueled by the rise of climate refugees, global economic hegemonies, billionaire influence, conflicts over land and water, the depletion of 99% of the planet's biodiversity, and the emergence of unprecedented diseases attributed to climate change. While this observation may appear stark and devoid of optimism, it is crucial to acknowledge that contemporary youth increasingly harbor a sense of disillusionment and diminishing trust in adults, viewing them as inadequate stewards of their collective well-being and futurities (Vamvalis, 2022; Han, 2022). As responsible adults, encompassing roles such as educators, scientists, engineers, and leaders, it becomes imperative to cultivate a heightened awareness. This awareness serves as the catalyst for conscientious efforts to actively disrupt and dismantle not only our own complicity but also that of others in perpetuating the constructs of the white colonial imaginary. Moreover, it entails sowing the seeds of authentic, responsible, and

reciprocal narratives that prioritize critical eco-relational significance, fostering a collective commitment to a sustainable and meaningful future (Whyte, 2018).

It is within this mind and heartspace that I position myself across the papers shared in my dissertation—as well in the collective engagements focused on moving toward the liberatory futures they represent. Furthermore, in hopes of being a responsible elder and ancestor, in the continued words of Pratim Sengupta, “I am led here by students and ex-students, who offer imaginaries for integrating intersectional narratives of suffering and resilience with algorithms of complexity. They show us the value of solidarity and listening together as computational experiences that can heal our pain.” (2020,p.3)

Whilst making a declaration of my commitment to embody and enact radical caring, I recognize that I must do so as a rogue, rigorously striving to inspire, support and lead against a dominant current designed and determined to wash me, and fellow rogues, away. This recognition and cellular remembering, does not and did not wither my resolve, but continues to galvanize me as I consider the rogue settler educators, student Earth Guardians and their peers highlighted in this dissertation—engaged in a rigorous processing of co-becoming, assuming dual roles as teacher-learners, who embraced collectivity, reciprocity, and mutuality. Together they operated within a framework of refusal, directing their efforts toward the utilization of knowledge as a potent tool for the eradication of oppression (Del Vecchio, Spady & Toomey, 2018). Courageously and resolutely, they endeavored to "forge critical consciousness as part of creating the world we can get behind rather than only describing the one we reject in front of us" (Said, 1983, p. 283).

Rooted in a genuine appreciation for the concerted efforts of educators and students, as well as the collaborative endeavors among teachers, students, and their peers, it is imperative to

underscore that the attainment of our accomplishments, as well as the nuanced understanding of what remains unattained, hinges upon a foundational knowledge base. This knowledge is cultivated through the lens of critical theory, with a specific emphasis on critical race theory (Bhaskar, 1975; Ladson-Billings, 2009; Delgado & Stefancic, 2023) and Indigenous realism (Wildcat, 2010; Whyte, 2020). Throughout the duration of our partnership, educators were equipped with a spectrum of critical theories and pedagogical frameworks, including critical realism theories, through various channels such as professional development, grade-level collaboration, curricular development, and instructional strategies. These provisions served to furnish educators with a solid foundation upon which to anchor their sensemaking, engage in critical meaning-making, and contextualize their actions within a broader framework.

Building Capacity to Educate for a Future Justly Responding to Racial Realism

A realist approach to Anti-racism and Anti-coloniality education necessitates the discontinuing and demystifying of ideologies that colonization and racism will or can decline over time or with approaches of anti-bias training, and/or access models and methods of diversity, equity, and inclusion—all which simply result in tokenization, cultural and racial gaslighting, extraction and exploitation of BIPGM (Black, Indigenous, People of the Global Majority), as a human resource for nuanced modes of settler comfort and saviorism (Milner, Harmon, & McGee, 2021). I work from the commitment that merely adding white gaze “cultural” approaches (Paris, 2019) and damage-centered, victim narratives (Tuck, 2009) as curriculum addendums—under the guise of cultural relevance or social justice—will only continue to manufacture racial oppression and settler colonialism, as intended in the original design of public schooling in the U.S. Without calling out and calling into light the white epistemic and ontological dominance which has been operationalized as the dominant norm—as

it has defined and determined the purpose and methodologies of teaching, learning, and society—the educational system will uphold white epistemic domination as *modus operandi* “because racial oppression is already a structural problem, conducting schooling as usual ensures that race-based inequality will continue” (Gilborn’s cited in Leonardo, 2013, p. 17). Without pulling into precise perspective the ways that schooling, as an institutionalization of settler colonialism, fuels and provides bodies and minds for on-going coloniality, we will forever be sacrificing the socio-ecological belonging, rights and futurities of BIPGM communities, generations of children, and our collective selves.

Coloniality and racism are not static or temporally bound, they are both dynamically fluid and mutating as society and social conditions evolve and unfold—and yet they are also susceptible to disruption and dismantling (Liboiron, 2021). Embracing Anti-racism with a racial realist stance means deeply understanding that, “the permanence of racism means that racism does not consist of ahistorical, individual, or aberrational events but rather is endemic to and a normal part of American life (Matsuda, Lawrence, Delgado, & Crenshaw, 1993), including education (Ladson-Billings & Tate, 1995), science (Harding, 1993), and science education (Parsons, 2014)” (Sheth, 2018, p 39). To take on a realist stance of colonization means to hold true the TribalCrit tenant that “that racism has become so deeply ingrained in society’s and schooling’s consciousness that it is often invisible” (Brayboy, 2005, p.428).

To be Anti-colonial means to deeply understand that “coloniality survives colonialism. It is maintained alive in books, in the criteria for academic performance, in cultural patterns, in common sense, in the self-image of peoples, in aspirations of self, and so many other aspects of our modern experience. In a way, “as modern subjects we breathe coloniality all the time and everyday” (Maldonado-Torres, 2007, p.243). This reality exists since contact-invasion where

“the structure of settler colonialism has been maintained by eradicating and punishing Indigenous, Black, Brown peoples” (Patel, 2018, p. 102).

Therefore engaging in Anti-racist and Anti-colonial research for liberatory ends through education is particularly provocative for teachers working within the belly of the beast of our westernized education systems which indoctrinates white culture supremacy and colonial logics and agendas (Dietrich, 2016) through ethnocentric, zero-epistemological mandated curriculum, coupled with race-neutral practices (Shah, 2021) and teacher professional development that reifies settler-false consciousness (Kulago, 2019). Therefore, taking up Kathrine McKittrick’s idea that “discipline is empire” (McKittrick, 2020), I take a position at the inner walls of discipline to create cracks, fissures, and desettle from the inside of the empire.

Recognizing the ongoing, current and escalating impact of this concoction of domination and disaster, as a former K-12 educator, as a woman of color passed through the machinery of this system, and as a scholar standing alongside other scholars committed to the exploration of “how we might create learning environments liberated from ethnocentrism imposed by Western science and science education (Bang, Marin, & Medin, 2018; Barton & Tan, 2018; Mensah, 2019)” (Warren et.al., 2020, p. 279). I present this dissertation research as both an offering to the efforts and invitation to continue to see forward facing insights in the designing of an anti-racist and anti-colonial educational Other-wise- as “both a horizon and also being lived in the present tense” (Kaba, 2021, as cited in, Tachine and Nicolazzo, 2022, p. 9) within that “space of decolonial in the colonial” (Patel, 2022, p xi).

Methods: Using Design Based Implementation Research to Build Teacher Capacity for Orchestrating Anti-racist and Anti-colonial Un/Learning

To achieve the aims described above, I have incorporated key tenets from Design-Based Implementation Research (DBIR) (Penuel, et al., 2011) guided by social practice theory (Bell, et al., 2012; Lave & Wenger, 1991), and In-relations methodological practice (Tachine, & Nicolazzo, 2023) alongside Indigenous Eco-critical and critical race theory.

The research practice partnership utilized methods and principles of design based implementation research (DBIR) to build social networks of educators at various scales, levels, and settings. “Design-based implementation research can help develop local capacity by fostering cohesion among networks of local actors tasked with implementing change, and by creating designs for routines and coordination mechanisms that can help innovations travel readily along those networks and that themselves can travel to new contexts.” (Penuel et.al., 2011, p.334) DBIR is guided by principles that focus on addressing persistent problems of practice, from multiple stakeholders' points of view, that engages educators, subject matter specialists, and educational researchers in collaborative, iterative design and develops knowledge and theory while also building capacity for continuous improvement (Penuel et al., 2011). “DBIR ideally produces more scalable designs and a deeper understanding of the contexts of science education, particularly how these contexts arrangements produce patterns of educational outcomes we observe today and the patterns we hope to produce tomorrow.” (Penuel et.al., 2011, p. 282). Therefore, as a DBIR project, guided by these principles, with aims to promote Anti-racist and Anti-colonial education at multiple scales, levels and settings within a district, the power and potential of the social network of educators, researchers and district partners was leveraged and nurtured. Efforts to facilitate mutualistic and in-depth, broad implementation of

educational change with the project's social network were aligned to the following research informed conjectures (Penuel et.al, 2016):

Conjecture 1: Efforts to promote sustained, mutualistic interaction will be more effective if researchers join and contribute to existing professional networks of educators.

Conjecture 2: Deep interactions between researchers and educators can facilitate access to and interpretation of research and changes to educators' and researchers' practice.

Conjecture 3: Co-design that involves key boundary spanners will facilitate high-depth, mutualistic interactions between researchers and practitioners, provided those boundary spanners can successfully link people and resources across networks.

Conjecture 4: Multi-tiered partnerships organized around boundary objects help coordinate activity within systems and support boundary spanning within districts.

Throughout the research project researchers, educators and organizational leaders participated as co-learners during Anti-racist and Anti-colonial professional development. Due to the intimate and critical content of the professional learning, meaningful interactions were scaffolded and shared among all participants. Application of co-learning was facilitated across the social network through the co-designing and co-constructing of curriculum. Both the professional development that transpired over 15 months and the curriculum were boundary objects supported by the instructional, cultural and intellectual expertise I brought into the research practice partnership network as a boundary spanner.

Throughout the research project and my dissertation, a central focus will be on grounding the inquiry in my own cultural intuition (Bernal, 1998). This approach, aligning with Bernal's concept of reflexive, embodied *conocimiento*, permits the integration of the "politics of spirit" into the research process (Bernal, 2016, p. 2). Additionally, the adoption of ethnographic storytelling methodology will be employed as a deliberate act to further incorporate Chicana

feminist epistemologies (Calderón, D., et. al., 2012) and relational research into the dissertation. Stories have the inherent power to center humanity, creating narrative spaces that facilitate *felt knowledges* (Harjo, 2019; Million, 2009) and a storied understanding. This approach becomes especially poignant and necessary in the current socio-political landscape marked by hegemonic oppressive forces determined to trade lived, living and unsecured future living of BIPGM, and multispecies kin in place of fables of dominant cultural epistemic superiority narratives of status quo and foreboding socio-ecological challenges.

Furthermore, I engage in the dreaming of, and designing of teacher education and research with the wholehearted aim to reflect Kim TallBear’s approach of “standing with” and “towards faithful knowledges, towards co-constituting my own knowledge in concert with acts and claims of those I inquire among” (as cited by Liboiron, 2021, p. 25)—in good feminist practice of not “fixing or saving” but rather expressing “political kinship and alter-relations” which understand that although the distribution of colonial violence is unbalanced, with whiteness as complicit, collectively we are threatened (Liboiron, 2021, p. 25). However, to do so requires great forethought and critical care for how educational innovation and teacher capacity should be designed and infrastructured across various scales and networks for sustainable and sustained transformation—especially when this work is conducted within district-sanctioned implementation initiative at the systems-level scale.

Research Context & Participants

I came into this research study as a continuation of my critical heartwork journey of transforming science education to embrace emancipatory teaching practices and generationally and culturally liberatory learning. This pursuit has evolved from my middle school classroom, into several districts and organizations as the Social Focus initiative starting in 2018. The research that will

be presented in my dissertation will be centered on Social Focus praxis teacher and student classroom learning that occurred during the 2021-2022 timeline.

During the 2021-2022 timeline, 122 teachers from three districts attended Social Focus praxis professional development with the option to participate at two scales. The Educators Series was a five-part professional development sequence of Social Focus praxis learning over the course of the 2021-2022 school year, this option was open to educators across districts and leadership roles. The second option was designed for educators in the Edmonds school district who agreed to participate in the Teacher Advisory Board (TAB). The TAB cohort included the 5 core Social Focus professional development trainings provided to the Educator Series cohort with an additional 5 professional development learning opportunities, including in-person, all day learning labs. During the 2021-2022 school year TAB teachers were also supported by university researchers in their classrooms as they began to integrate learning from professional development into their teaching practice and through the implementation of Social Focus science units.

It is important to note that throughout the arc of learning the realities of teaching, learning and living during the COVID-19 global pandemic were ever-present and constantly transmuting, elevating the visceral pulse of humanity in education, necessitating care and responsiveness. Therefore, the design of the learning for both cohorts of educators included synchronous online group learning, supported by curated multimedia resources, learning done asynchronously between sessions, with the intention to support and scaffold new and upcoming learning, as well as encourage collaboration and application into classrooms and district spaces. The Social Focus praxis approach to teacher learning supported the building of shared capacity within social networks by connecting educators to resourced expertise and mediating tools

(Penuel et. al., 2016). Additionally, throughout the learning, for both cohorts, the undertaking of Anti-racist and Anti-colonial instruction was designed to extend within and across networks through the use of shared tools, such as the Social Focus framework, Critical Liberatory framework, Spectrum of Representation, Social Focus Instructional Practices and Unit development process.

The Lines of Research

Holding the need and desire to do this critical dreaming, remembering, designing, infrastructuring, and implementing, transformative work is needed from preschool to graduate school; I narrow my sights of my research to elementary school at district-level scale. A core heart-centric reasoning for this focus is rooted in the years of experience as a middle school science teacher witnessing and endeavoring to reverse the impact of the colonial mind making and white supremacy spirit abusing machinery of the educational system uniquely presented in the ways students—particularly Black, Brown and Indigenous youth—regarded science and the disregard of themselves as scholars, scientists and innovators. Therefore, despite patronizing colonial narratives of children, especially young children, which I discuss further in my papers, specifically paper two and three, I situate this myself within a network of district elementary school educators, to think in the company of Vintimilla and Pacini-Ketchabaw (2020) who assert “pedagogy demands that early childhood education become ever more attuned to the situated complexities in which we live, pedagogy requires that we carefully and attentively study the conditions that create early childhood education, and that early childhood education creates” (p.15). And given the conditions and complexities of elementary schools and their learning ecologies, both teacher and student, this research recognizes the deep “interventionist nature of the work at hand” (p. 244) which has resulted in the implementation of a myriad of educational

products, to varying degrees of outcomes, often due to “imposed theoretical view” (p.249), cultural and racial incongruencies and bias, “where objects are taken into authentic educational contexts without any coordinated attempt to engage in theoretically framed empirical research on related educational phenomena” (Bell, 2004, p. 245). Therefore, with a sharp focus and clear agenda to address the multi-dimensional and multifarious ways that anti-racism and anti-coloniality are infused within elementary school science education, aimed to disrupt childrens’ inherent onto-axio-epistemic trajectories of socio-ecological identity development, brilliance and securities. Additionally, given the reverent and complex differences and sacred kinship between anti-racism and anti-coloniality, a rigorous theoretical pluralism is required, and employed to best ensure the design-based research responsibly and response-ably (Bell, 2004) to forge “pathways toward educational self-determination and sovereignty through allowing learning to be collective, democratized, and emergent from Land and community” (Meixi et.al., 2022, p. 3). Accordingly, grounded in the notion of answerability (Nelson & Shotton, 2022), the dissertation research I engaged in is multiscalar with the following focal research questions:

Paper System Level Focus, Title, and Purpose	Corresponding Research Question(s)
<p>Paper 1 (Chapter 2):</p> <p>Level: District Network of Elementary School Teachers</p> <p>Title: Documenting Elementary Teacher (Un)Learning Pathways Towards Antiracist and Anticolonial Science Education Across a District</p> <p>Purpose: To develop a typology of the disparate cultural learning pathways of elementary school teachers as they engage in anti-racist and anti-colonial learning</p>	<ol style="list-style-type: none"> 1. How can we design sustained professional learning for elementary teachers from across a public school district on anti-racist and anti-colonial approaches to education? 2. How do elementary teachers recognize and disrupt white epistemic dominance in science and science education in practice? 3. How does a network of elementary teachers engage in extended learning about anti-racist and anti-colonial science pedagogies? How do they take up such approaches and associated understandings? How do they resist them?

<p>Paper 2 (Chapter 3):</p> <p>Level: Curricular, Teacher Pedagogy, and Student Outcomes</p> <p>Title: Disrupting white Geology in Science Education by Centering the Eco-Relational Mattering of Consequential Lands: A Second Grade Student Case Study of Possibility</p> <p>Purpose: To document and theorize the capacities of a young learner to engage in eco-relational caring practices during a science geology unit</p>	<ol style="list-style-type: none"> 1. What are the possibilities for disrupting settler colonial geo-imaginaries and cultivating second-grade students' socio-ecological caring and relational reasoning as Land Guardians? 2. What are the implications of this socio-ecological caring and relational reasoning by second-grade students for anti-racist and anti-colonial science pedagogy?
<p>Paper 3 (Chapter 4):</p> <p>Level: Student Focus</p> <p>Title: Just worlding design principles: Childrens' multispecies and radical care priorities in science and engineering education</p> <p>Purpose: To develop an existence proof of student learning and relational thinking focused on environmental and multispecies justice in science and engineering.</p>	<ol style="list-style-type: none"> 1. When situated in learning spaces of desettled engineering education, how do students engage in the co-construction of epistemic agency to promote their ontological security and perspectives on worlding just worlds? 2. What engineering design priorities do students provide the field of engineering education and engineers, for considering Multispecies, LandAirWaterStars, community and global futurities?

Taken together, these three articles provide substantial insight into the pedagogical, curricular, and learning dimensions of a sustained district implementation effort focused on liberatory education. In the following chapters, I present these three research articles. I will then conclude with a synthesis of the high-level conclusions and implications of this work.

References

Bell, P. (2004). On the theoretical breadth of design-based research in education. *Educational psychologist*, 39(4), 243-253.

Bell, P., Tzou, C., Bricker, L., & Baines, A. D. (2012). Learning in diversities of structures of social practice: Accounting for how, why and where people learn science. *Human Development*, 55(5-6), 269-284

Bell, P. (2019). Infrastructuring teacher learning about equitable science instruction. *Journal of Science Teacher Education*, 30(7), 681-690.

Bernal, D. D. (1998). Using a Chicana feminist epistemology in educational research. *Harvard educational review*, 68(4), 555-583.

Brayboy, B. M. J. (2005). Toward a tribal critical race theory in education. *The urban review*, 37(5), 425-446.

Calderón, D., Bernal, D. D., Huber, L. P., Malagón, M., & Vélez, V. N. (2012). A Chicana feminist epistemology revisited: Cultivating ideas a generation later. *Harvard Educational Review*, 82(4), 513-539.

Delgado, R., & Stefancic, J. (2023). *Critical race theory: An introduction* (Vol. 87). NyU press.

Dietrich, R. (2016). Made to Move, Made of this Place: *Into America*, Mobility, and the Eco-Logics of Settler Colonialism. *Amerikastudien/American Studies*, 507-525.

Han, R. J. (2022). *Designing Justice-Centered and Intersectional Environmental and Climate Learning Across a Professional Network* (Doctoral dissertation, University of Washington).

Harjo, L. (2019). *Spiral to the stars: Mvskoke tools of futurity*. University of Arizona Press.

Ladson-Billings, G. (2009). Critical race theory in education. *The Routledge international handbook of critical education*, 110-122.

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge university press.

Liboiron, M. (2021). *Pollution is colonialism*. Duke University Press.

Meixi, Moreno-Dulcey, F., Alcalá, L., Keyser, U., & Elliott-Groves, E. (2022). When learning is life giving: Redesigning schools with indigenous systems of relationality. *AERA Open*, 8, 23328584211062587.

Million, Dian. 2009. "Felt Theory: An Indigenous Feminist Approach to Affect and History." *Wicazo Sa Review* 24 (2): 53–76. doi:10.1353/wic.0.0043.

Milner, H. R., Harmon, M. D., & McGee, E. (2021). Critical Race Theory, Teacher Education, and the "New" Focus on Racial Justice. In *Handbook of Critical Race Theory in Education* (pp. 364-378). Routledge.

Nelson, C., & Shotton, H. (2022) (Re)considerations of answerability through gifting In Patel, L., & Yang, K. W. (Eds). *Weaving an Otherwise: In-Relations Methodological Practice*. Stylus Publishing, LLC.(pp.92-106)

Patel, L., & Price, A. (2016). The origins, potentials, and limits of racial justice. *Critical Ethnic Studies*, 2(2), 61-81.

Penuel, W. R., Fishman, B. J., Haugan Cheng, B., & Sabelli, N. (2011). Organizing research and development at the intersection of learning, implementation, and design. *Educational researcher*, 40(7), 331-337.

Penuel, W. R., & Fishman, B. J. (2012). Large-scale science education intervention research we

can use. *Journal of research in science teaching*, 49(3), 281-304.

Penuel, W. R., Bell, P., Bevan, B., Buffington, P., & Falk, J. (2016). Enhancing use of learning sciences research in planning for and supporting educational change: Leveraging and building social networks. *Journal of Educational Change*, 17(2), 251-278.

Sengupta, P. (2020, January). Re-orienting design: an unbearable pain. In *V. Hand, S. Vossoughi and S. Jurow (Co-Chairs), Special Session (Identity & Learning Strand), International conference of the learning sciences*.

Shah, N. (2021). *Racial Equity and Justice in Teaching and Teacher Education: Progress, Tensions, and Open Questions*. Spencer Foundation

Sheth, M.J. (2019). Grappling with racism as foundational practice of science teaching. *Science Education*, 103, 37-60

Tachine, A., & Nicolazzo, Z. (Eds.). (2023). *Weaving an otherwise: In-relations methodological practice*. Taylor & Francis.

Vamvalis, M. (2022). Nurturing embodied agency in response to climate anxiety: Exploring pedagogical possibilities. *Teaching in the anthropocene: Education in the face of environmental crisis*, 119-130.

Vintimilla, C. D., & Pacini-Ketchabaw, V. (2020). Weaving pedagogy in early childhood education: On openings and their foreclosure. *European Early Childhood Education Research Journal*, 28(5), 628-641.

Wildcat, D. R. (2010). *Red alert!: Saving the planet with indigenous knowledge*. ReadHowYouWant. Com.

Whyte, K. (2018). Settler Colonialism, Ecology, and Environmental Injustice. *Environment and Society*. 9. 125-144. 10.3167/ares.2018.090109.

CHAPTER 2:

Documenting Elementary Teacher Learning Pathways Towards Anti-racist and Anti-colonial Science Education Across a School District

Introduction

As is, educational research, district and classroom efforts for educational justice are bound up in equity propaganda, spinning narratives about increasing access to standardized dominant knowledge, thereby increasing acculturated participation, of course with the benevolent inclusion of diversity, as curricular accessory with tokenized diversity representation. This acts as a narcotic illusion, rooted in and spun by Euro-westernized and colonial logics, producing a guise of settler false consciousness, spreading variants of white supremacy, through palliative double morality. This stupor, as critical conscious coma, requires anti-racism and anti-coloniality to begin the waking and healing process in urgent hope for finding a true antidote to educational injustice. Given the appeal of settler false consciousness and the grip and saturation of white supremacy culture and settler coloniality within education, I ask: Is it possible for white teachers to become anti-racist and anti-colonial in their instructional practice? Coupled with this question is: What is in jeopardy should white settler educators not become both anti-racist and anti-colonial? The answers to the last question live within tired data about achievement, and exist in the ghosts of BIPGM¹ student dreams, potentialities, futurities, and our lost and threatened ecosystems (de Olivera Andreotti et.al., 2015). Therefore, I situate this research at the

¹ The abbreviation of BIPGM stands for Black, Indigenous and People of the Global Majority. This abbreviation is purposely used instead of BIPOC, POC or diverse in an attempt to address both the marginalization and collapsing of persons identified as Brown, not to claim this sufficiently mitigates the pervasiveness of these common practices which continue to center whiteness as norm.

intersection of these queries with the assertion that the disruption of coloniality and racism necessarily requires the transformation of teacher professional development to move beyond normative confinements of teaching and learning designed to maintain and advance white and human supremacy (Arada, Sanchez & Bell, 2023).

This research aims to shed light on the effective design and implementation of teacher professional development initiatives within research practice partnerships, with a focus on fostering anti-racist and anti-colonial pedagogies and curricula, to document ideological shifts over an arc of time. Providing such teacher education, operating at the district level, affords an opportunity to examine instructional guidance frameworks rooted in liberatory education principles at systems-level scale. Contrary to conventional views of infrastructure as static entities, this study adopts a design-based research approach that emphasizes the dynamic processes involved in (re)designing educational infrastructures for liberatory possibilities—as outlined by Bell (2019). Undertaken within the context of public schooling, this transformative endeavor operates on the premise that an educational paradigm centered on liberation is not only viable but also urgently overdue. The objective of this work is to offer illuminative insights and advocate for radically caring approaches to supporting educators' journeys of unlearning and cultivating anti-racist and anti-colonial ideologies and pedagogies. The teacher development facilitated and documented in this design-based research is conceptualized as engaging teachers in fostering their political clarity and personal and professional commitment to anti-racist and anti-colonial teaching practices. Moreover, given the relative dearth of empirically grounded research on anti-racist (see Blakeney, 2005; Mensah, 2019 as notable exceptions) and anti-colonial professional development for educators (see Kulago, 2019 as another exception), this study aims to fill this gap by tracing the dynamic learning pathways of teachers' (1)

sensemaking, (2) critical meaning-making, and (3) situated action(s) over an extended period of (un)learning—to better understand the complex oscillations and evolutions towards and away from and towards settler false consciousness and horizons of anti-racist and anti-colonial (co)becomings and instruction.

Theoretical Foundations

Cultural Learning Pathways: A Sociocultural Accounting of Learning Across Structures of Social Practices

Dreier (2009) elucidated the diverse social practices in which individuals engage, emphasizing the influence of local contexts on shaping knowledge and expertise (as cited in Bell et al., 2012). Leveraging established theoretical frameworks for cultural learning pathways, this study attends to the socio-material, relational, affective, and power-laden dimensions of learning processes (Bell et al., 2012; Nasir et al., 2020). By examining these pathways, the research aims to comprehend the chains of personally consequential activities and sense-making, which are culturally diverse and temporally extended (Bell et al., 2012). This approach reveals how cultural learning is taken up in relation to learners' identities, emphasizing relational and affective elements (Nasir et al., 2020). I use this view to understand how teacher learning is accomplished across a range of social practices that include: (1) sensemaking, (2) critical-meaning making, and (3) situated actions.

Sensemaking, an intricate process inherent to educators' professional lives, encompasses the navigation of a myriad of inputs and messages concerning educational reform and best practices, often rife with contradictions, within the local educational milieu (Allen & Penuel, 2014). While extant literature underscores the contextual factors shaping reform initiatives, such as leadership support and access to professional learning opportunities (McLaughlin & Mitra,

2001), it is the sensemaking endeavors of teachers that serve as pivotal catalysts for transformative shifts towards critical meaning-making and sustained action. Sensemaking, characterized as an active process of assimilating and structuring information, operating the level of epistemology, necessitates grappling with ambiguity and uncertainty (Allen, 2020) to "structure the unknown" (Waterman, 1990, p. 41). This ambiguity, likened to shocks, possesses the potential to invigorate sensemaking processes and should thus be intentionally cultivated, particularly in endeavors aimed at fostering anti-racist and anti-colonial education (Allen, 2020). It is imperative to acknowledge that the depth of sensemaking may vary, potentially leading to the reinforcement of entrenched cultural norms and assumptions (Phillips, 2019), if not accompanied by supportive, sustained engagement with critical content within a sociocultural context. Thus, the design of learning environments must prioritize providing supportive structures conducive to sustained critical engagement, facilitating transformative sensemaking processes among educators.

Critical Meaning-Making: In the dynamic process of sensemaking, characterized by the grappling with epistemic destabilization, critical meaning-making emerges as a profound response within the situated contexts of educational practice. This transformative process, as expounded by Phillip (2011) and Madkins & McKinny de Royston (2019), represents a pivotal moment wherein individuals engage deeply with affective modes of processing to navigate ideological shifts in understanding. By delving into multi-dimensional reflexivity, critical meaning-making serves as a catalyst for reshaping not only epistemic perspectives but also axiological and ontological stances, aligning them toward emancipatory praxis—a concept championed by scholars like hooks (2000) and Freire (1970). The intricate interplay between epistemology, ontology, and axiology underscores the depth of critical meaning-making,

highlighting its significance in fostering nuanced perspectives and transformative action within educational contexts. Moreover, the nuanced engagement with ideological shifts facilitated by critical meaning-making, as articulated by Philips (2019), further underscores its profound impact on ontological and axiological realms, thus emphasizing its pivotal role in facilitating comprehensive transformative processes.

Situated Actions: Grounded in cultural-historical activity theory which holds that “transformative agency and willful action are of crucial importance in performing and shaping work” (Engeström & Sannino, 2020, p. 2). As architects of professional development and advocates for transformative progress, it is imperative that designing teacher professional development take into deep consideration that educators' actions are situated within particular social and political contexts. Professional development design should account for the varied responses of teachers, recognizing their positionalities and striving for transformative action within communities of practice (Lave & Wenger, 1991). Centering anti-racism and anti-coloniality in professional development design aims should address power dynamics inherent in the learning environments created, shared and situated within them. (Adams et al., 2022) By focusing on situated actions as units of analysis, this research aims to understand shifts in learning from knowing to doing academic practice (Dohn et al., 2019). By examining situated actions as units of analysis pivotal insights can be gleaned into the depth of sensemaking and critical meaning-making taken up providing essential indicators of white supremacy culture pillars which act as barriers of transformation and manifest as embodiments and enactments of white ideological resistance (Pewewardy et al., 2018).

This sociocultural theory of cultural learning pathways is used to understand the detailed learning processes and shifts in sociomaterial practice that relate to teachers taking up anti-racist

and anti-colonial instructional approaches. In order to theoretically understand what that learning involves, it is necessary to understand the kinds of processes associated with how teachers take up and enact a critical settler consciousness with respect to how whiteness and coloniality operate in public schooling.

How Unveiling False Consciousness Can Awaken Critical Settler Consciousness in Teaching and Teacher Education

Efforts to establish anti-racist and anti-colonial instructional frameworks within teacher learning necessitate an introspective and explicit examination of the systemic entrenchment of white supremacy and colonial logics within education with deep consideration of educators' cultural pathways of transformation, and patterns of regression. Historical contextualization and systematic identification of prevalent practices and methodologies in teacher learning constitute foundational aspects for comprehending the landscape of educational opportunities (Bell, 2019). Concurrently, it is imperative to recognize and address the perils of faux-equity practices that perpetuate false consciousness (Liou, 2020; Mills, 1997). False consciousness manifests as a failure to acknowledge the pervasive influence of whiteness, colonialism, and coloniality in shaping the generation and dissemination of knowledge, resources, and opportunities. This ignorance perpetuates socio-subliminal structures that uphold and propagate colonial ideologies and agendas, further entrenching the pervasive "educational racial contract" (Leonardo, 2013) within educational institutions and the mindsets of educators. Such an endeavor aims to unravel the intricate web of systemic biases and inequities woven into the fabric of our schooling systems to weave a new liberatory, educational *Otherwise*.

False Consciousness, Equity, and Racism: Equity best intentions, particularly best intentions undertaken within enclosures of dominant culture paradigms and mindsets are fraught with deceptive approaches, harmful expectations and troublesome outcomes, maintaining racism

and the ever-present achievement gap (Leonardo & Grubb, 2018). In education, such best intentions have evolved from an era of multiculturalism, shifting to equitable education, popularly taken up as DEI (Diversity, Equity and Inclusion) initiative and efforts. DEI at its core asserts that by exposing Brown, Black, and Indigenous students to a spectrum of diverse role models who have gained entry into traditionally white-dominated spheres of success, will serve as compelling evidence that achieving success is not only feasible but also a goal worth pursuing, irrespective of its associated challenges and costs. Such initiatives are reminiscent of 18th century paternalistic benevolent racism whereas, “White Americans, stated simply, were encouraged to take on the ‘burden’ of looking after the inferior races they colonized” (Esposito & Romano, 2014, p. 5). Attempts to mitigate educational injustice via DEI premises, commonly through tokenized cultural inclusion in mainstream curriculum, and/or STEM career workforce goals and narrative, are rooted in neoliberal race-neutral myths of meritocracy (Singh, 2018) ultimately serving as acts of racial and cultural gaslighting, upholding pillars of white supremacy, feeding settler false consciousness—thereby detouring authentic potentialities of anti-racism (Gorski, 2019).

Cultural inclusion initiatives, often implemented to fulfill district Diversity, Equity, and Inclusion (DEI) objectives, can inadvertently perpetuate settler false consciousness and insidious racial and cultural gaslighting. This occurs through an overemphasis on diverse cultures while neglecting to address white culture, thus implying that persistent disparities in academic achievement among BIPGM students are inherently tied to their cultural and racial backgrounds. This narrative persists under the assumption that education, rooted in settler colonialism, remains inherently objective, neutral, and normative.

The Framing of Anti-Racism and Anti-Coloniality for Liberatory Teacher Education

Critical analyses within the frameworks of whiteness and settler studies have identified attributes, traits, structures, and systems within white culture that reinforce white supremacy (Kulago, 2019; Ladson-Billings, 2021; Liboiron, 2021; Matias & Boucher, 2023). These attributes, which I refer to as *pillars of white supremacy culture*, serve as foundational elements upholding dominant white culture as the societal norm. In my research and in the professional development provided to educators, I argue that true educational justice necessitates a thorough examination and critique of these pillars of white supremacy culture. This calls for a radical and compassionate direct approach that involves understanding concepts such as white arrogance, white innocence, white ignorance, and white saviorism, particularly as they manifest within educational contexts.

Pillars of white supremacy: If education is truly committed to the disruption and countering of on-going educational onto-epistemic violence inflicted upon Black, Brown and Indigenous students, efforts of cultural competence necessarily would include the exploration and interrogation of white supremacy culture. White studies has done much to illuminate the complexities, historicities, manifestations and mechanizations of whiteness and white supremacy culture in education (Matias & Boucher, 2023). Building from these foundations of theory, I assert that white supremacy is upheld and maintained uniquely through pillars of white innocence, white arrogance, white ignorance and white saviorism—individually, interconnectedly and interchangeably. These structurally, systemically and socioculturally enabled, normalized, pillars of white supremacy act as barriers of transformation, derailing momentum towards anti-racism and anti-coloniality.

In contrast to soteriological attempts to absolve white individuals through pious intentions and performative displays of white guilt or fragility, the perpetuation of white

innocence is sustained. White innocence can be viewed as a weapon and a perceived entitlement granted by white supremacy. This pernicious variant, evolving over time, finds its origins in the justification of massacres during the Christian crusades, the colonial narrative of civilizing societies leading to genocide and ecological exploitation (Said, 2012), and current efforts to erase racialized histories and impede affirmative action, thereby upholding education as a domain of whiteness. The pervasive nature of education as white property not only fosters white innocence but also perpetuates it within the materiality and identities of white teachers, particularly among white women.

White innocence, often mislabeled as white fragility, is prevalent in education—largely due to the predominant presence of white women teachers in the US. Many of these educators inherit and exhibit attributes of innocence as an innate privilege, consciously and subconsciously wielded often at the expense of non-white students and colleagues. The equating of innocence with white women, rooted in centuries of violence, has tragically resulted in the marginalization and even death of countless Black, Brown, and Indigenous individuals. White feminism, critiqued by scholars such as Ruby Hamad (2019), author of "White Tears, Brown Scars," traces its origins to settler colonial societies, where white women are assigned dual roles as complements to white men but rendered powerless due to their perceived need for constant protection, particularly from racialized peoples. This enduring trope serves as a protective mechanism and a source of white arrogance, perpetuating the belief that being a white woman makes one untouchable to the realities of racism and colonialism as they manifest in society.

White arrogance, like white innocence, is multifaceted. It exists within the very materiality of whiteness, cellularly as if a sense of white superiority, garnered from generations of white supremacy as genetic material passed on, forming connective tissue between whiteness

and power, as power is enacted and embodied within systems, structures and socio-political spaces. In the realm of education, white arrogance fueled the justification of violence in residential schools. It echoed in the sound of sheared hair from Native children (Adams, 2020), the insertion of lye soap between the teeth of Native children, and the immersion of Mexicans in kerosene baths, all under the guise of assimilation – an attempt to erase native languages and darken skin to better conform to whiteness (Khanmalek, 2021). Such acts were arrogantly deemed righteous, disregarding the epistemic destruction and genocidal violence they wrought.

The tendrils of this history of white arrogance persist, infiltrating education with narratives that equate proximity to whiteness with equity and altruism, particularly for white educators. White arrogance manifests in the denial and deliberate ignorance of colonial origin stories and their ongoing manifestations, perpetuating the classroom, curriculum, and instruction as instruments of white dominance and colonization. This saturation of whiteness within the educational infrastructure and ideologies perpetuates a cycle of hyper-validation, reinforcing and imposing white ways of being and knowing upon marginalized communities. In this cycle, the absence of diverse perspectives and relationality is disregarded, creating a void of expertise and understanding, characteristic of what can be termed as white aggro-ignorance. This term describes the state of arrogance and lack of awareness exhibited by individuals steeped in dominant white culture, asserting their own perspectives while dismissing those of non-white communities and experts within the educational system.

White ignorance exists both explicitly, through overt expressions of bigotry and white supremacist beliefs, and implicitly, through willful misunderstandings that enable white individuals to avoid confronting the realities of race and racism. Additionally, settler ignorance, related to white ignorance yet specific to the indoctrinated erasure of Indigenous peoples,

throughout time, involves the rejection of acknowledging colonialism as an act of genocide and an ongoing colonial project. To understand white ignorance, Mills (2007) describes it as "an ignorance militant, aggressive, not to be intimidated, an ignorance that is active, dynamic, that refuses to go quietly—not at all confined to the illiterate and uneducated but propagated at the highest levels of the land, indeed presenting itself unblushingly as knowledge." In education, white ignorance is fiercely protected, evident today in the push to penalize the inclusion of critical race-related content, to end affirmative action, and even in the removal of language or initiatives revolving around equity or social justice, further distancing learning from the possibilities of *critical liberatory presencing* (Sanchez, 2024; Arada et.al., 2023). With this understanding of white ignorance Blakeney (2002) calls for praxis driven and problem posing anti-racist teacher professional development structured for awareness awakening dialogue.

White saviorism, espouses a false generosity (Freire, 1998) and self-righteousness, reminiscent of colonial, christian missionaries, aimed at saving the damned Othered, from the perils of their assumed brokenness as non-whiteness, through the shepherding of their conversion and accretion of whiteness for access and inclusion to empire. The neoliberal white savior, the DEI white champion, has been valorized in the media through movies such as *Dangerous Minds*, *Blindside* and even *Hidden Figures*, reifying the power of whiteness to save the unsaveable, usually singular individuals deemed worthy of investment, often through the rendering of their onto-axio-epistemic cultural and racial identities (Camarota, 2011). White saviorism is embodied and enacted in many forms- all forms requiring an essentializing, damage-centered perspective (Tuck, 2009) of non-white communities and individuals. This perspective relegates relationships into conditional, transactional, and hierarchical arrangements based on the indentured productivity of the subordinate, favoring the benevolent white savior's ego and

reifying white power rather than liberation.

Despite the entrenched challenges presented by the pillars of white supremacy, it is essential for white settler educators to undertake the arduous task of recognizing and deconstructing these pillars within themselves, their instructional methodologies, and their classrooms, as they represent critical points for intervention. Examining supposedly race-neutral practices (Shah, 2021; Jupp et.al, 2019), instructional approaches, and epistemologies as default mechanisms upholding "whitestream" education (Grande, 2003, p. 6) creates opportunities for liberation by exposing and challenging mindsets that perpetuate injustice, while facilitating the reorientation of teaching practices towards centering justice, Black, Brown, and Indigenous histories, futurities, significance, knowledge, and ontological security (Bang & Marin, 2015). Therefore, echoing Rafia Zakaria's sentiments (Etiesit Samuel, 2021), the critique of embodied and enacted white cultural supremacy should be construed not as a rebuke but rather as a radically caring (Rivera-McCutchen, 2021; Aswad, 2024) invitation to embark on a journey of healing, critical hope, and authentic transformation. Embracing this perspective necessitates a commitment to a path of anti-racism and unmooring oneself from conceptualizations of normalcy as neutral and simultaneously racially hierarchical and inevitable. Through anti-racism educators demystify life as is, as inevitable, to begin not only to see, but work to disrupt within their situated positions and positionalities.

Colonialism, Coloniality, and the Call for Anticoloniality: Colonization did not only occur through physical seizing and displacement of peoples from land, but also through the colonization of minds. (Asante in forward to Dei & Kempf, 2006, p. ix) Colonization, which takes up the "organizing language of race" (Wolfe, 2006, p. 387), involves the forceful political, physical, and intellectual occupation of space, through the displacement of Indigenous peoples,

laying the foundation for settler-colonialism, colonial and neo-colonial relations, begetting coloniality. Coloniality according to Nelson Maldonado-Torres (2007): “coloniality survives colonialism. It is maintained in books, in the criteria for academic performance, in cultural patterns, in common sense, in the self-image of peoples, in aspirations of self, and so many other aspects of our modern experience. In a way, as modern subjects we breathe coloniality all the time and everyday” (p. 243). This leads to the portrayal of Eurocentric knowledge as neutral, universal, and apolitical, resulting in the suppression of alternative knowledge systems. Imperial and colonial actions have established biased narratives and perspectives of the Other, perpetuated through ideologies, discourses, institutions, scholarship, and imagination. (Mignolo & Walsh, 2018; Smith, 1999) To come to truly understand the devastating influence of coloniality one must become critically conscious about the fact Asante elevates that: “Nothing is sacred in such a system as it powers its way toward the extinction of the wills of the imposed upon with one objective in mind: the ultimate subjection of the will to resist.” (Dei & Kempf, 2006, p. ix) Thus, taking up the anti-in anti-coloniality is the diligent embodied and enacted practice of resistance, disrupting and countering coloniality as it exists and is propagated within the situated spaces as resistance, which for this research means taking up anti-colonial education- a vital imperative to delve into the underlying colonial logics, ideologies, and agendas that informed and continue to inform the very purposes of education (Kulago, 2019; Brayboy, 2005; Calderon, 2014; Garcia & Shirley, 2012; Lee & McCarty, 2017; Shirley, 2017).

To take up anti-coloniality it is essential to understand the purpose, prospect and power of the ‘anti’ in anti-coloniality particularly in considering education as place for “epistemic delinking from colonial matrices of power (Mignolo, 2009)” (quoted in Warren et.al, 2020, p. 278). Anti-colonial education challenges current forms of education, viewed as remnants of

neo-colonial indoctrination. It aims to counter the ongoing devaluation of Indigenous knowledge and cultures. Indigenous scholars and activists strive to evaluate and improve school curriculum, textbooks, teaching methods, and classroom practices to ensure relevance and inclusivity. (Dei, 2008) Anti-colonial education aims to weed out the deep roots of colonial epistemic dominance, social injustice, narratives of ecological dominance to render an educational landscape that is guided by Indigenous knowledges and futurities as a best way forward towards collective continuance (Whyte, 2013). Therefore, where anti-racism calls for loss, a rendering of power, asking us to constantly consider, what am I willing to give up in order to participate in anti-racism (Shah, in review), anti-coloniality offers a (re)new(ed) rendering of Indigenous futurities, not absent of settlers (Tuck & Gaztambide-Fernández, 2013), a more pluralistic, socio-ecological sustainable, just society.

As a collective of critical theories, anti-racism and anticoloniality provides a vision of what must be forfeited as current and on-going power constructs, knowledge projects and acts of eradication, to (re)gift a pathway forward in harmony with natural and spiritual law (Banyacya, 1992) for collective survivance (Sabzalian, 2019). Recognizing the vast complexities and realities embedded in Anti-racism and Anti-colonialism as separate justice projects both deserving of singular focus, given the intersectionality of our BIPGM youth that are the all-too young gladiators in the public school arena, there is validity in working towards advancing a “multiplicity justice project” (Tuck & Yang, 2018). Which means taking up educational research with the explicit intent to promote “co-resistance movements as a way to build relationship between the Black radical tradition and critical Indigenous studies that Sandy Grande suggests working through a framework of refusal, focusing on the knowledge as a means to eradicate

oppression” but rather “collectivity, reciprocity and mutuality” (Del Vecchio, Spady & Toomey, 2018, p. 138).

Anti-racist and anti-colonial approaches are vital to a more just science education—making it an important lever for the transformation of education more broadly. Science education, despite false claims of being apolitical, has been uniquely tooled to erase the expertise, experiences and existence of BIPGM cultures and communities (Bang et.al., 2018). “Embedded in science learning environments (e.g., through curricula and assessments), settled expectations replicate the racialized structures predicated on white supremacy and settler colonialism through the erasure of Black, Brown, and Indigenous presences and histories, and the privileging of white settler ways of knowing and being (Bang et al., 2012; Harris, 1993)” (quotes in Arada et.al., 2023, p. 78). Informed and inspired by scholars in the field of education who have dedicated themselves to fostering anti-racist and anti-colonial science teaching and learning across diverse contexts, my research draws from various approaches and focuses. These include youth and community-led, justice-centered pedagogies (Morales-Doyle, 2017; Patterson & Grey, 2019), revitalizing and resurgent informal Indigenous science learning (Bang & Marin, 2015; Pugh, McGinty, & Bang, 2019), science learning that centers Indigenous and Black refusal and futurities (Nxumalo, 2021, 2020; Nxumalo & Cedillo, 2017), as well as fundamental research conducted at the intersections of formal and informal learning, honoring students' cultural pathways for learning (Bell, et al., 2012; Bricker & Bell, 2014; Nasir, et al., 2020; Stromholt & Bell, 2017).

Understanding that educators can only tell the stories they know and map the paths they are conscious of, dreaming of and designing for liberatory science and engineering education means restorying and restructuring teacher learning for liberatory situated learning that disrupts

and counters the master's narrative as starting place to present a different mirror (Takaki, 2012) on science, teaching and learning. This means providing pluralistic counterstories and designing professional learning sites to be counterspaces for co-deconstructing, whitestream curriculum (Solorzano & Yosso, 2001). Given the layered complexity of such a proposal of teacher learning I lean on and engage theoretical pluralism in the design of learning environments (Bell, 2004) weaved together with deep felt knowledge(s) (Harjo, 2020; Grande, 2015)— with themes of activism, constellar cultural and experiential expertise. Guided by this constellation of theory and professional experience, I engage in the dreaming of, and designing teacher education and research, with the wholeheartedly aim to reflect Kim TallBear's, approach of “standing with” and “towards faithful knowledges, towards co-constituting my own knowledge in concert with acts and claims of those I inquire among” in good feminist practice of not “fixing or saving” but rather “political kinship and alter-relations” which understand that although the distribution of colonial violence is unbalanced, with whiteness as complicit, collectively we are threatened (quotes from Liboiron, 2021, p. 25). Therefore, at the core of this work is radical care, meaning that despite and in spite of the absence of racial and ecological topics of consequentiality and urgency in teacher learning and science classrooms, the intent of this radically caring teacher learning approach is to build and fortify a “quiet movement” (Tuck, & Yang, 2018, pg.123) movement of teachers as guardians for change.

Holding a commitment to the radical care of teachers as critical methodology for change as well as the pervasiveness of white supremacy and coloniality, it is necessary to ask, is it even possible for science and engineering learning to be race-visible (Hambacher & Ginn, 2021), critical settler consciousness nurturing and anti-colonial? And if so, “how do we hold people accountable for wrongdoing and yet at the same time remain in touch with their humanity

enough to believe in their capacity to be transformed?” (hooks, 1998) And if all of that is possible, how can teacher education be infrastructured and designed to do so? With these questions in mind I boldly say that not only is it possible, it is required. Therefore this study, as part of my life’s heart work, aimed to address the following research questions:

1. How can we design sustained professional learning for elementary teachers from across a public school district on anti-racist and anti-colonial approaches to education?
2. How do elementary teachers recognize and disrupt white epistemic dominance in science and science education in practice?
3. How does a network of elementary teachers engage in extended learning about anti-racist and anti-colonial science pedagogies? How do they take up such approaches and associated understandings? How do they resist them?

Methods: Infrastructuring and Studying Teacher (Un)learning Pathways through Design-Based Implementation Research

Setting and Participants

For this NSF-funded research practice partnership project, the research focused exclusively on educators within a suburban school district network, spanning 15 elementary schools in the Pacific Northwest. All of the teacher participants were members of the Teacher Advisory Board (TAB) which included twenty-seven kindergarten through sixth grade case study teachers, with twenty-five identifying as white women and two as white males. Recruitment for the TAB cohort occurred during various summer professional development opportunities for science instruction provided by the district, which were co-designed with university research assistants funded by the NSF grant, including myself. While teachers were invited to participate in the two-year

research project, membership in the TAB was voluntary, with incentives such as clock hours and stipends provided for participation.

The study included 27 elementary teachers from a mid-sized city in the Pacific Northwest, all members of a Teacher Advisory Board (TAB) for the project. The TAB cohort served as case study teachers participating in the research practice partnership over the course of 15 months. The educators centered in this research resembled the racial and gender demographic average of classroom educators in the nation, with 25 of the participants identifying as white women, and two identifying as white males.

Methods of Data Collection

Throughout the 15-month duration of the partnership, data for this study was collected across three primary contexts: (1) documentation of professional development (PD) activities, (2) observation of classroom instruction and planning, and (3) individual interviews and interactions with teachers. Data collection was conducted with the support of the project's four other graduate research assistants. Professional development activities were meticulously documented through various means, including video recordings of PD sessions totaling approximately 36 hours, exit tickets completed by participating teachers, and collection of artifacts from the PD such as video transcripts, online chat logs, breakout room artifacts, and researcher notes.

Data collection regarding classroom instructional practice and the implementation of curricular interventions as situated actions involved gathering data from multiple sources. However, due to the timing of the project, which coincided with the return to in-person instruction following the COVID-19 pandemic shutdown, the number of in-person classroom observations varied. On average, there were eight recorded classroom visits per case study teacher.

Criteria for classroom visits were carefully established, encompassing the use of a shared observational protocol. This protocol was specifically designed to comprehensively document various aspects of the observed lesson, including the content covered, instructional practices employed, student participation, and any connections to the content from PD and/or the Social Focus framework. The observational protocols served as a reference point for the development of case study teacher analytical memos, which played a crucial role in the subsequent research analysis.

In addition to classroom observations, data sources on teacher practice included student artifacts, researcher fieldnotes and analytical memos, and notes from grade-level team meetings (if planning sessions were observed). It was also common for teachers to communicate via email and text with members of the research team. Relevant emails and text messages were considered data sources, subject to the participants' approval.

In summary, data sources used in this analysis of teacher (un)learning pathways included: (1) Professional development artifacts: video transcripts (~43 hours), chats, interactive platforms (~14), slides, surveys (4), exit tickets (~36), (2) Classroom observations (of 29 classes), curriculum slides (8 decks), student artifacts (28 pieces of student work), (3) Teacher interviews (29 total interviews) and communication (numerous emails, texts, and individual conversations with 14 teachers).

The Design and Implementation of the Arc of Professional Learning Through the Research-Practice Partnership

In design-based research, the design of the learning environment is part of the research methods since enactment of the design opens up spaces for the phenomena-of-interest—and other emergent phenomena—to become available for empirical study. Recognizing the nuanced role of

district educators as both contributors to the perpetuation of coloniality and racial inequity, as well as potential agents of change capable of implementing anti-racist and anti-colonial education, presents a critical opportunity for practice (Bell, 2019). This perspective brings into focus the fundamental question posed by Philip Bell (2019): "Can we leverage collective teacher learning associated with standards implementation to advance liberatory goals?" (p. 681). To address this question, my research identified liberatory goals as the establishment of a networked justice improvement community. This necessitated the deliberate design and development of a proactive and iterative infrastructure for an arc of teacher (un)learning within a district network, operating at various scales, and producing cohesive yet distinct curricular products that could be enacted in classrooms (Bell, 2019).

In pursuit of this objective, the study adopted a critical Design-Based Implementation Research (DBIR) approach that integrates elements of design research and implementation research to conceive, refine, and assess interventions within authentic contexts (Fishman et al., 2013). DBIR provides a structured framework for developing and testing innovative solutions while also considering the complexities of implementation, adoption, and sustainability in real-world educational settings. By employing DBIR, the research aimed to bridge the gap between theoretical frameworks and practical application, ensuring that the interventions designed were not only theoretically sound but also feasible and effective in addressing the identified challenges within the district's educational landscape (Penuel et.al., 2011).

In this section, I elaborate on the structured progression of professional development (PD) learning environment and teacher engagement—which I developed with the assistance of my co-facilitator, Dr. Kelsie Fowler. This PD initiative was implemented for district teachers within the framework of a research practice partnership spanning 15 months. The PD trajectory

is delineated into five distinct phases, comprising multiple PD sessions and situated learning engagements. Each phase builds upon the preceding one in a methodical and sequential manner. This approach is rooted in the belief that the effectiveness of PD is contingent upon its ability to address targeted areas of improvement while also contributing to broader educational transformation. By systematically organizing PD content, resources, partnership engagements and activities within a coherent progression, this research sought to optimize the outcomes of PD interventions at both the micro (individual sessions) and macro (overall PD program) levels.

The design of each PD session was infrastructured using a knowledge-reflection-action (KRA) praxis model, as a consistent substrate of intervention for desired outcomes (Bell, 2019). Blakeney (2005) emphasizes the pivotal role of praxis in fostering impactful teacher professional development, especially in tackling issues related to racism and fostering racial consciousness among educators. Building on Brown's (2002) epistemological approach, Blakeney highlights the importance of teachers delving into the societal impact of racism and their own racial identities. This process should be designed to facilitate teachers' understanding of critical theories, enabling them to navigate the intricate emotional terrain of racism effectively. Blakeney also emphasizes that effective praxis-oriented professional development must go beyond theoretical understanding to translate knowledge into practical classroom strategies. Insufficient professional development that merely skims the surface, as discussed by Sleeter and Bernal (2002), may result in regression, teachers falling back on familiar practices, thereby impeding progress in addressing racial issues within the educational context.

Through the KRA praxis approach teachers were provided multi-dimensional situated learning experiences to engage in *currere* which encourages participants to “confront difficulty in order to loosen its grip” (Pinar, 2004). By engaging teachers a KRA praxis cycle of *currere*,

teachers were supported and encourage to participate in pedagogical improvisation which, “works to bridge the theoretical value of the design principles to their pedagogical actuality, showcasing the ways design principles are not static theoretical constructs but fluid and pedagogically contextual artifacts for deepening and expanding teaching and learning that reflect the core political, ethical, and educational values of the learning context” (Jackson, 2021, pg 62).

The multi-dimensionality of the KRA approach is akin to the parallel anti-racist research and IPER framework developed by Dr. Niral Shah, which posits the existence of "four interconnected components of antiracist learning: ideation, practical, emotional, and relational change" (Shah, in review, p. 1). The alignment between the IPER framework and the KRA praxis model utilized in this study, while adaptable due to individual learning dynamics, can be conceptualized as follows: (a) the knowledge segments of the PD sessions foster ideation, (b) the reflection segments encourage emotional and relational development, and (c) the action segments align with the practical dimension. However, it's important to note that this alignment does not fully encompass the sensemaking, critical meaning-making, and situated action engagement dimensions used in the present study—which are highlighted in this research as pivotal for comprehending both transformation and regression, as later discussed in the paper.

The development of the PD arc using a KRA praxis model served as a foundation for integrating anti-racist and anti-colonial content, guided by the Social Focus Framework (Sanchez, 2024). The Social Focus Framework (see Appendix A1) revolves around liberatory principles, critical consciousness, consequential concern, and critical liberatory presencing, acting as pedagogical and theoretical anchors, as well as moral compasses and scaffolds for shaping teacher learning and curriculum development toward transformative student education. Extensive research has explored the efficacy and value of utilizing design principles as a

transformative method in education (Herrington & Reeves, 2011; Jackson, 2021; Engle & Conant, 2002; Sandoval, 2014).

The Social Focus Framework's principles have been refined through an iterative process involving collaboration with multiple K-12 teachers, education leaders, and researchers since its inception in my middle school science classroom in 2017. This framework is firmly rooted in critical social theory, as delineated by Zeus Leonardo (2009), underscores the significance of criticism in fostering quality education, positing that the depth of learners', in this case the teachers', analytical engagement correlates with the educational quality they receive. It also encourages learners to critically analyze institutional and conceptual hurdles, particularly those perpetuating domination or oppression. Furthermore, critical social theory advocates for a language of transcendence alongside critique, aiming to cultivate alternative and less oppressive social structures.

This recognition of the potential for transcendence is integral to the design, development, and implementation of the professional development (PD) arc. Additionally, the approach is grounded in sociocritical theories of learning, as highlighted by Kris Gutierrez (2008), who emphasizes the powerful learning outcomes that emerge when individuals, both children and adults, engage meaningfully in communities of practice and grapple with real-world problems that hold significance for them. In the subsequent section, I delineate how these theoretical underpinnings and methodological strategies were put into action with the teacher cohort over a period of 15 months. The explanation of the phases below follows the KRA praxis elements as they were implemented with notes about how implementation was not aligned to the original design particularly in regards to phase three.

Phase 1 (September-December): Launching with Social Focus Framework Principles of Critical Consciousness and Critical Liberatory Presencing

Phase one of the professional development (PD) initiative focused on instilling critical consciousness among teachers using the Social Focus framework. This phase commenced with a deep dive into how white supremacy culture permeates personal identities, educational landscapes, and broader societal contexts, including the fields of science, technology, and engineering. Teachers were equipped with knowledge and tools to critically analyze and challenge manifestations of white supremacy culture in education and science. To facilitate this learning, teachers engaged with Kenneth Jones and Tema Okun's "15 Characteristics of White Supremacy Culture" to discern common traits indicative of white supremacy (Jones & Okun, 2000). This approach aimed to cultivate critical awareness of these manifestations, which later became recognized as pillars of white supremacy in phase four of the PD.

Moreover, teachers delved into a historized understanding of colonialism's adverse impacts, contextualizing colonization within science and education policies (Latour, 2008). They also explored how white supremacy culture influences national education policies such as The Elementary and Secondary Education Act, Every Student Succeeds Act, and No Child Left Behind. Through sensemaking processes, teachers were encouraged to challenge the notion of schooling systems as historically neutral and just.

Another essential aspect introduced in this phase was "Critical Liberatory Presencing," designed to counter tokenized representations of Black, Indigenous, and People of Color (BIPOC) individuals in educational settings. This approach aimed to move beyond surface-level diversity and inclusion efforts, emphasizing the necessity of centering BIPOC expertise in shaping scientific knowledge and activism. Reflective sessions were conducted to validate teachers' agency in sensemaking and critical meaning-making. The Spectrum of Representation

and the Critical Liberatory Presencing framework (see Appendix A3 & A2) served as guiding tools to facilitate discussions on erasure and intervention points within curriculum and practices.

Action in phase one focused on fostering a community of learners and leaders (Penuel et al., 2011). Teachers engaged with critical frameworks while building relationships based on trust and transparency, challenging traditional PD models by prioritizing critical reflection and dynamic action research. This phase laid the groundwork for developing critical consciousness and embracing anti-racist ideologies and practices within educational contexts.

Phase Two (December-March): Focusing on Consequential Concern and Social Focus Curriculum Development

Moving into phase two, the PD shifted its focus to consequential concern within the Social Focus framework. This principle prompts educators to question how, for what, for whom, and with whom science is taught (Phillip et al., 2018). It underscores the understanding that all science and engineering topics are linked to socio-ecological consequences and calls for a more honest and generationally competent approach to science education.

Teachers were introduced to the concept of consequential concern to redirect the teaching and learning focus from individual achievement to students' intellectual health (Bang, 2020). This approach encourages students to critically analyze societal challenges stemming from colonialism and white supremacy, positioning them as active participants in addressing complex issues.

Implementing the Social Focus Framework principle of consequential concern necessitated sustained reflection and supported resources due to the teacher gap (Love, 2019) among white teachers, stemming from a sheltered worldview devoid of BIPGM realities and experiences. Designing teacher learning experiences to achieve such goals required addressing

"epistemological collisions" and ideological wrestling (Kulago, 2019). Radical care for teachers during this transformative process was crucial to "delink from epistemic colonial matrixes of power" (Mignolo, 2009).

The action phase in curriculum development aimed to avoid replicating western thought traps (Leonardo, 2018). The Social Focus Iterative Design Process and Pedagogical Commitments (see Appendix A4 & A5) served as guiding tools for teachers to develop emergent curriculum and instructional strategies aligned with anti-racist and anti-colonial pedagogies. Phase two emphasized the practical application of (un)learning experiences through curriculum development, promoting critical consciousness and liberatory teaching practices.

Phase 3 (March through May): Stabilizing, Synthesizing and Centering Anti-coloniality through Indigenous Pedagogies of Practice

In phase three, the focus expanded on the tenets of anti-coloniality by delving deeper into colonialism, settler colonialism, and anti-colonial theory. Indigenous science pedagogies, practices, and theories were introduced to counter traditional PD approaches perpetuating white culture mindsets and colonial agendas. The lifelong journey of enacting anti-coloniality and desettling science education was emphasized, urging participants to reject knowledge as capital and critically assess performative actions like Land acknowledgments (Funes, 2022).

Participants were challenged to disrupt colonial narratives and practices, differentiating between settler colonialism and settler coloniality. The inadequacies of Westernized science in addressing socio-ecological challenges rooted in settler colonialism were highlighted (Bang, 2016), emphasizing the importance of Indigenous science knowledge centered on relationality and interconnectedness (Meixi et al., 2022).

Reflection sessions and collaborations with university researchers focused on concluding efforts in teaching Social Focus units and gathering feedback on incorporating Indigenous perspectives into curriculum. Although time constraints limited the action sequence related to anti-coloniality and Indigenous science pedagogies, phase three significantly contributed to participants' understanding of anti-colonial theory and practices.

Phase 4 (August-December): Journeying Towards Enactment and Embodiment of Anti-coloniality and Anti-racism

Phase four commenced with in-person (un)learning conferences aiming to further destabilize settler colonial logics and white supremacy ideologies. These sessions engaged teachers in critical reflection and discussions on disrupting acts of colonialism and coloniality. The emphasis on Anti-coloniality and Anti-racism aimed to guide teachers in developing interventions promoting sensemaking, critical meaning-making, and situated actions to counteract regression and foster transformative processes.

Despite the unforeseen termination of graduate researcher time, subsequent PD sessions continued online, focusing on deepening teachers' critical meaning-making and situational actions. Radical care was provided to support teachers in processing the end of the partnership, culminating in the development of a Social Focus backpack resource with tools and frameworks to sustain ongoing (un)learning and collaboration.

Phase 5: Foreclosure and Rogue Resistance

Phase five, although curtailed due to the premature end of the partnership, witnessed teachers uniting in resistance and forming their own community of practice to continue (un)learning and collaboration. This phase underscored the resilience and determination of teachers to uphold

anti-racist and anti-colonial ideologies and practices, highlighting the lasting impact of the PD initiative.



Figure 1: Scope and sequence of PD across phases.

Analytical Methods

The data were analyzed through the following procedural phases for the purposes described. This ultimately allowed for the identification of distinct cultural (un)learning pathways of teachers taking up an anti-racist and anti-colonial pedagogical approach.

Data sources were aggregated for each case study teacher. Data was gathered and aggregated per teacher alongside teacher memos written by researchers about the experience and practice of those teachers. Sources of data were systematically aggregated on a per-teacher basis to ensure rigorous analysis and interpretation. A diverse array of sources was collected and organized from multiple channels for each of the 27 educators involved in the study. These sources encompassed

a comprehensive range of quantitative network survey data and qualitative data comprising teacher reflections, Zoom chat comments, exit tickets, surveys, teacher interviews, professional development (PD) transcripts, and grade-level team meetings, as well as associated artifacts. This data collation was conducted alongside the compilation of teacher memos by myself and the graduate student research team. The aggregation process involved attention to detail to ensure a comprehensive portfolio of evidence and artifacts was created to make initial assertions. While the collation of data and development of the analytical memos provided generalizable insights into each case study teacher, the memos did not provide a thick description of “detail, context, emotion, and the webs of social relationships that join persons to one another” (Denzin, 1989, p. 83) correlated to the shared, yet varied situated learning experiences and processes over time. Therefore, with aims of “particularizability rather than generalizability” to “uncover the different layers of universality and particularity that are confronted in the specific case at hand- what is broadly universal, what generalizes to other situations, what is unique to the given instance” it was necessary to take another pass at the data analysis (Erickson, 1986, p. 130).

Open coding of teacher data as it relates to sensemaking, critical meaning making, and situated action. The next phase of analysis involved organizing and examining the various data sources for each teacher as it unfolded across the five phases of professional learning with respect to the three core dimensions of the analytical framework (sensemaking, critical meaning making, situated action). (Lofland & Lofland, 1995) Following the approach outlined by Corbin and Strauss (1990), an open coding method was employed to delineate the spectrum of engagement and enactments undertaken by teachers, guided by the theoretical framework of sensemaking, critical meaning-making, and situated action. The resulting coding schemes for these three

dimensions are presented in Tables 1, 2, and 3 . Within each of the tables, sub-codes were determined—which for sensemaking and critical meaning-making fell under ideological categories as related to the professional development content themes and engagements. In regards to the situated action, sub-codes were developed based on teacher enactments and applied (un)learning within classroom instruction and during grade-level collaboration. There is variation within specific sub-codes as it relates to antiracist and anticolonial science instruction. These value-based differences were interpretively taken into account in the subsequent identification of different teacher learning pathways.

Table 1: Coded Dimensions of Teacher Sensemaking

Sensemaking (SM): How teachers negotiate meaning from a variety of, often conflicting, messages they encounter in their local environments; it describes how they "structure the unknown" (Waterman, 1990, p. 41). It operates on the level of epistemology.

Sensemaking Subcodes	Description of Teacher Sensemaking Actions
SM:Personal	<ul style="list-style-type: none"> • Personal orientations as limiting factor for anticolonial/antiracist (un)learning, teaching
SM:Equity	<ul style="list-style-type: none"> • Instruction and participation framed through lens of equality—not equity nor justice • Equity and Inclusion as baseline grounding • All learning is cultural • Content [science] is not neutral; access to content as equity is not neutral
SM:DEI/Representation/CLP	<ul style="list-style-type: none"> • Teachers/teaching with inclusion of diverse perspectives is better than tokenism • Recognizing curricula and systems equity strategies focus on tokenized images of BIPGM scientists in curriculum // Teachers and school leaders rely on tokenized images of BIPGM scientists in curriculum (district mandated & created) & instruction • Teachers grappling with DEI; need ways to engage in critical and liberatory presencing of BIPGM knowledge beyond inclusion/tokenism
SM:Instruction	<ul style="list-style-type: none"> • Reflecting on science and science instruction matters • Commitment to dominant curriculum is not supportive of ways of knowing/learning • Teachers are positioned to embody & uphold white supremacy culture

	<ul style="list-style-type: none"> • Teachers are positioned to uphold white supremacy culture but can become antiracist and anticolonial • Teaching that centers students intellectual healthy & consequential learning disrupts the pace of dominant curriculum & teaching practices • Self-reflection as social actor within education • To become an antiracism and anticolonial teacher takes willing rendering • antiracism and anticoloniality and are needed in all content areas, not just science • Teaching requirements often contradict what it means to responsibly take up antiracist and anticolonial approaches
SM:Curriculum	<ul style="list-style-type: none"> • Expresses EuroWestern view of science as central to science instruction • Science & science learning is not neutral but endeavors to be positive and practical • Pragmatic concern about the intensity of work involved • curriculum and instruction embedded within practices of white dominant culture traits/values/macroaffirmed ways of knowing • Tension with curricula as fixed object, time intensive to change • Curriculum needs to be audited using an anti-racism and anticolonial lens • Science learning content is connected to consequential climate, justice, and ecological matters • Desettling curriculum includes antiracist and anticolonial counter pedagogies and content
SM:Teacher Learning	<ul style="list-style-type: none"> • Revoicing of PD learning goals • Reducing antiracism and/or anticolonial content to prior knowledge • Antiracist and anticolonial content and value not provided in teacher prep/district training/curricular materials • Novel and productive professional learning • Antiracism and anticoloniality are big concepts and need more time for learning • Antiracist and anticolonial (un)learning is epistemically & affectively destabilizing • Antiracist and anticolonial content inclusion needs specific pedagogical approaches
SM:Students	<ul style="list-style-type: none"> • Equity, justice-oriented, antiracist content/approaches are for diverse populations • Students cultures should be included in learning • Students are sources for determining depth of learning • Centering of students lived experiences supports PD goals of anti-racism • Centering students lived narratives/intellectual health as counter pedagogy • Students are harmed by dominant/mainstream/status quo instruction-curriculum
SM:Anticoloniality	<ul style="list-style-type: none"> • Anti-coloniality (decolonization / Indigenous ethnic studies) is situated in the past and includes legends and myths • Addressing anticoloniality is a nuanced practice of tokenized representation/inclusion • Colonial logics/colonialism consumes/destroys nature and Indigenous peoples

	<ul style="list-style-type: none"> • Anticolonial instruction counters false/deficit/detached/aggressive narratives of LandAir Water • Anticoloniality includes multispecies justice and more-than human critical & liberatory presencing • Becoming anti-colonial is about collective power, not individualism • Presencing Indigenous Pedagogies, Peoples and Perspectives • Anti-colonialism sustains collective well-being • Anticolonial instruction counters reductive approaches through complex relationality
SM:Racism/ Antiracism	<ul style="list-style-type: none"> • Being white, in a white-dominanted system does not require critical consideration of positionality • Inclusion of racial injustice is not enough for meaningful antiracist instruction/learning • The knowledge & skills to center dignity-conferring antiracism is unknown/not taught/needed • Students could/should have learning experiences that include BIPGM expertise
SM:Barriers	<ul style="list-style-type: none"> • Racialized identities and communities pose important pedagogical considerations • white supremacy informs/is built into the structures of education

Table 2: Coded Dimensions of Teacher Critical Meaning Making

Definition of Critical Meaning-Making (CMM): Meaning-making that engages ideological shifts in understanding (Philips, 2019) often through affective modes of processing. It operates at the level of ontology and axiology in coordination with epistemology.

Critical Meaning Making Subcodes	Description of Teacher Critical Meaning Making Actions
CMM: Personal (R)	<ul style="list-style-type: none"> • Personal challenges have come up (e.g., confronting biases, white gaze dominates) as central to transformation • Regression is a pattern of progress—not an ideological, pedagogical permanence—but requires attunement • Transformation is a lifelong journey that requires rigor to continue to unlearn and learn and take action.
CMM: DEI/Representation/Critical Liberatory Presencing	<ul style="list-style-type: none"> • BPIGM representation as DEI strategy (tokenism) • Spectrum of Representation referencing • Making meaning out Critical Liberatory Presencing framework dimensions in connection to practice/education/materials • Curriculum without critical liberatory presencing is by default designed to uphold WSC • (general) Consequential Concerns; Critical & Liberatory learning to promote critical (settler) consciousness is needed in all content areas

<p>CMM: Curriculum & Instruction</p>	<ul style="list-style-type: none"> • Transforming curriculum and instruction is a daunting project • Generous reflection/auditing of current/prior practice poses opportunities for transformation • The system of education impedes transformation • Teaching and Learning that is consequentially centered fosters community <p><i>Progression:</i></p> <ul style="list-style-type: none"> • To know better is to do better but it is hard how to know how to do better • Learning should center socio-ecological care/understanding that Science and society includes multispecies/landsairwaterstar justice • Teaching antiracism & anticoloniality is an obligation to commit oneself to for the collective well-being of students. • Inclusion of antiracist and anticolonial content will require teacher to take responsibility for critical iterative research • Teaching that counters dominant culture approaches to education requires seeing youth as whole/deserving of their intellectual health being nurtured. • Teaching that counters dominant culture approaches de-centers teacher as source of knowledge <ul style="list-style-type: none"> • Teaching is isolating-(un)learning, auditing, (re)designing, critical curriculum in community is valued
<p>CMM: Teacher Learning</p>	<ul style="list-style-type: none"> • Teacher PD/Ed needs to go beyond fakequity and tokenism to be anti-racist or anti-colonial • Antiracism and anticoloniality are big concepts and need more time for learning • Desettling is a collaborative, iterative & integrated process of critical noticing, research, and refined practice • Becoming/(un)learning antiracist and anticolonial teacher is an on-going challenging, messy journey and practice yet worthwhile and necessary
<p>CMM: Students</p>	<ul style="list-style-type: none"> • Antiracism and Anticolonial learning is great but must have classroom value-to shift in practice • Students are capable and deserving of Antiracist and Anticolonial learning • Valuing instruction/learning that nurtures students' intellectual health, students' lives and experiences-that they are part of the narrative, not separate, even if it is in conflict with dominant culture/curriculum is essential. • Students are deserving and capable of expansive and consequential antiracist and anticolonial learning.
<p>CMM: Anticoloniality</p>	<ul style="list-style-type: none"> • Indigenous/Native peoples as romanticized or essentialized • Decolonization is valued but misunderstood and lacking PD • Indigenous representation is most often presented as tokenized stories from the past, as legends, not truth. • Colonization pushes progress at the cost of nature and POC communities well-being • Indigenous ways of knowing provide more hopeful ways of living than dominant white culture

	<ul style="list-style-type: none"> • Anticoloniality redefines/repurposes the classroom/learning to center healthy relations with Land and multispecies • Anti-coloniality calls for instruction that disrupts dominant narratives & agendas to center self-determined content from Indigenous communities to promote their thriving.
CMM: Racism/Anti-racism	<ul style="list-style-type: none"> • DEI work does not change the dominant system • Equitable representation needs to go beyond equity and tokenism to be anti-racist or anti-colonial • Antiracist (science) education needs to go beyond deficit-equity approaches of tokenism as supplementary inclusion • Centering BIPGM presence is key; Centering BIPGM presence is key, disrupting whiteness; WEIRD focus is key • White supremacy culture is present in our classrooms and requires critical reflection and noticing and (un)learning. • Antiracist and anticolonial resources/knowledge about consequential concerns and critical liberatory presencing is needed to desettle science • Performative inclusion supports white saviorism & white innocence • Antiracism and Anticolonial learning is interdisciplinary
CMM: Barriers	<ul style="list-style-type: none"> • BIPGM are cultural and epistemic resources to be extracted from for validation • Leadership in equity projects bolsters one's centering (e.g., through white arrogance or white saviorism) • Breaking down barriers of white supremacy is essential for transformational education • Science (other content) is situated in society's entanglements of race, colonialism and ecology-not void of it-supports white dominance • Teachers can embody and enact white-saviorism, ignorance, arrogance and innocence • Education and teaching (and society) is designed to enable pillars of white supremacy.

Table 3: Coded Dimensions of Teacher Situated Action (identified by PD Phase or as representing baseline, emerging, or progressing/transforming levels of understanding)

Definition of Situated Action (SA): Operating at the level of methodology (in relation to axio-onto-epistemic details).

Situated Action Subcodes	Description of Teacher Situated Actions
SA: Personal	<i>Baseline/Regression</i> <ul style="list-style-type: none"> • Attendant/Participation in the moment book clubs, race and equity committees etc. • Curriculum Design & Development: Present at grade-level learning collaboration

	<p><i>Emerging</i></p> <ul style="list-style-type: none"> • Curriculum Design & Development: Engaging in adaptation of mandated curriculum through process of integrating Social Focus lessons <p><i>Progressing/Transforming</i></p> <ul style="list-style-type: none"> • Personal Practice: Intentional critical personal learning/growth/connections/engagement in (un)learning antiracism and anticoloniality inform practice (instruction, development of materials, shifts in self-positioning, ...) • Personal Practice: Shifting participation in school community (shifts include new roles, increased vocalization of antiracism and anticoloniality = settler responsibility) • Personal Practice: Engaging in the messiness, the difficulty of applying/integrating antiracism and anticoloniality in the classroom • Personal-Meta-awareness of praxis journey-reflection to refigure the substantive work to be done • Curriculum Design & Development: Collaboratively engaging in critical research to reconstruct, redesign, curricula for classroom use • Curriculum Development: Taking responsibility to center consequential climate issues in elementary units/lessons—often involves critical research • Curriculum Design & Development: Making BIPGM histories present in materials / instruction (i.e., curricular representation); often involves finding critical liberatory presencing sources and integrating on their own
SA: Instruction	<p><i>Regression</i></p> <ul style="list-style-type: none"> • Instruction: Mutating Critical Liberatory Presencing into cultural appropriation/tokenism • Maintaining dominant pedagogies; (Re)centering settled, funneled curriculum • Resisting students' elevation of/engagement of consequential concerns, personal narratives, Not attending to students pathways of thinking/learning/engagement; teacher maintaining course of curriculum as written • Barriers of adult power and dominant colonial logics-transformation happens or does not happen here <p><i>Emerging</i></p> <ul style="list-style-type: none"> • Inconsistent uptake of Social Focus grade-level curriculum-did not critically engage students/content(interest convergence instruction-often due to maintaining white innocence/ignorance) • Instruction: Centering students' general critical sensemaking <p><i>Progressing/Transforming</i></p> <ul style="list-style-type: none"> • Curriculum as Methodology-Teaching Social Focus lessons as method for moving forward/towards antiracist and anticolonial instruction • Inclusion of student discourse on socio-ecological consequential matters <i>in conjunction</i> with dominant pedagogies/ideologies • Inclusion of student discourse on socio-ecological consequential matters as an expressed <i>countering</i> of dominant pedagogies/ideologies • Desettling (white) students' conceptions of science as race- or justice-neutral • Desettling by modeling ("even if that means pausing the lesson") connected to

	<p>personal growth/desettling</p> <ul style="list-style-type: none"> • Desettling dominant colonial narratives by centering/making space for multispecies justice/presencing and ecological care/responsibility • Science and engineering have been/is practiced/led by cultural communities around the world across history-centers the critically liberatory presence of BIPGM • Desettling dominant colonial narratives by including antiracist and anticolonial climate change/justice content • Integration of antiracist and/or anticolonial content and/or pedagogical commitments across content areas • Student Focus: Science and engineering is situated in consequential socio-ecological entanglements; giving space for critical and speculative student discourse-engagement. • Student Focus: Science & Engineering occurs within the spaces, time, realities of communities; positioning community as stakeholders to be presenced
SA: Network/ Community	<ul style="list-style-type: none"> • Valuing of and participating in partnership learning ecologies-reflection & curriculum adaptation work; his is positive yet identifies teachers who are more passively involved collaboration <p><i>Progression</i></p> <ul style="list-style-type: none"> • Curriculum Networking: Sharing/supporting teachers use of Social Focus units outside partnership (grade-level teaching partners, school teachers...) • Sharing of PD content, resources, learning experiences with others outside partnership (teachers, admin, family, friends...)

Collaborative analysis of individual teachers across all data sources. The five researchers on the team had worked with subsets of different teachers over the 15-month period. They had participated with the teachers in a range of contexts, developed memos from their observations of teacher practice, and communicated with teachers over phone, text, and email. To understand the learning pathways of specific teachers and how subsets of them were engaged in specific learning pathways, I worked with each of the other researchers to cross-check my analysis of teacher learning and action across the arc of the project. In this participatory approach to design research (Bang & Vossoughi, 2016), I looked for similarities and sought out disconfirming data to further inform the analysis to make further assertions regarding the range and particularities of teachers’ processes (sensemaking, critical meaning-making and situated actions) of engagement (Erickson, 1986). It was not practically possible given how the project was ended to engage in

traditional member checking with each teacher after the project had been disrupted. However, this collaborative analysis of researchers helped triangulate and highlight salient theoretical aspects of the teacher cases.

Analysis of patterned variation of teacher behaviors across professional learning phases to identify distinct pathways of engagement and learning. In the next phase of interpretive data analysis, patterns of sensemaking, critical meaning making, and situated action across the phases of professional learning were identified. These patterns are assertions made about the corpus of data from each teacher in the coded analysis (Erickson, 1986). See Figure 2 for an example coded analysis of one teacher at a specific phase of professional learning. This teacher case analysis revealed significant commonalities among subsets of teacher-cases in terms of the learning pathways teachers were engaged in over time. By identifying parallels between teacher cases and variations across distinct sets of cases, I was able to make assertions regarding how specific sets of teachers engaged in distinct pathways of engagement and learning. For example, a group of teachers engaged exclusively in sensemaking behaviors without critical meaning making nor related situated actions. They were identified as being on a *'non' performative settler pathway*. On the other hand, another group of teachers were engaged in deep sensemaking and critical meaning making that translated into anti-racist and anti-colonial situated actions in the classroom. They were identified as being on a *rogue settler diligence pathway*.

First Name	Phase 3: April-June	SM Themes	CMH Themes	SA Themes	Phase 4: Summer 2022
(Alaura)	How to help my white students not become white saviors? Something I continually struggle with myself		<ul style="list-style-type: none"> Teachers can embody and enact white-saviorism, ignorance, arrogance and innocence To know better is to do better but it is hard how to know how to do better 		CM [Personal Map]:
	[Interview 6.1.2022] I think, especially for me, as someone who is white and was raised pretty sheltered. That in that space I'm like allowing my students to express themselves and be themselves and have space for all of that. And understand that what I grew up with isn't the best for anybody, but certainly not my students of color. And I think you know, like them. The more I can learn, and the more I can be aware of the world, and how other people are moving and acting in the world is what I can do but it's really hard		<ul style="list-style-type: none"> CMH: Science and society includes multispecies/lands/air/water/star justice CMH: Personal challenges have come up (e.g., confronting biases) CMH: Centering BIPOC presence is key // Centering BIPOC presence is key, disrupting whiteness / WEIRD focus (?) 		SA [Helps lead and host summer learning and I love to host people way of practicing being a leader w doing the Anti-racist work. I think about going back to school for as sure that all of this (gestures with
	SA [May observation notes]: JB teaches the 3rd grade Puyallup Tribe lesson and opens with a lengthy land acknowledgement. ... This is the first time she has ever done this. She names Indigenous Peoples' contributions to science and need to let them control their own land as a climate change mitigation strategy—it was INCREDIBLY to witness this naming for such young students			<ul style="list-style-type: none"> SA: Instruction: Integration of anti-racist and/or anti-colonial content and/or pedagogical commitments across content areas Instruction: Science and engineering have been/is 	PO-ET-How are you working toward better next time. By embedding my teaching as possible Unlearn
	[Interview 6.1.2022] All of the resources that I like I've learned so much about like I think about like the soul fire farms lessons that I did and like learning about that Community and those people, and all the work that they're doing and how excited my students got when we learned about that and the ideas they started generating. Like it's I've learned a ton just especially I think about people and organizations that I didn't know existed, which is amazing for my own learning and then the fact that my kids are learning it along with me is so exciting, because I think it's good for me to model for them like I didn't even know this was a thing and we're learning about it together.		<ul style="list-style-type: none"> AR/AC resources/knowledge about consequential concerns and C&LP is needed to desettle science. Teaching antiracism & anticoloniality is an obligation to commit oneself to for the collective well-being of students. Teaching that counters dominant culture approaches to education requires seeing youth as whole/deserving of their intellectual 		PO-ET-How are you working toward better next time. By embedding my teaching as possible Unlearn
	[Interview 6/2/2022] Yeah I just think like after we read water protectors, and then they did that, like seesaw activity like how am I going to be a water protector, what does it mean for me to be a protector of something and the ideas that were generated and how excited they got and then, when we moved into persuasive writing after that and thinking about. Climate change and how, then they incorporated what they've learned in their science unit into their persuasive writing and then they would give these persuasive speeches to each other, and you can hear them, just like bouncing ideas off of each other and getting excited and you know, I think, especially with things like climate change it's so easy to get stuck in the we're all gonna die and the world's you know falling apart. And just that hope for like I can make changes thing is really cool and fun to see my students get excited		<ul style="list-style-type: none"> Indigenous ways of knowing provide more hopeful ways of living than dominant white culture Valuing instruction/learning that nurtures students' intellectual health, students' lives and experiences—that they are part of the narrative, not separate, even if it is in conflict with dominant culture/curriculum is essential Instruction: Desettle dominant 		[From the past two days, what is
	[May email to KF]: JB is naming she doesn't know of any examples of critical liberatory presencing for the spinning earth unit and needs to go and do research to figure this out—doesn't put it on KF. Then she does the research, drafts the ways this will be taken up in the classroom and seeks feedback.	<ul style="list-style-type: none"> AR & AC content and value not provided in teacher prep/district training/curricular materials 	<ul style="list-style-type: none"> Teaching antiracism & anticoloniality is an obligation to commit oneself to for the collective well-being of students. Inclusion of AR & AC content will require teacher to take responsibility for critical iterative research 	SA-intentional critical personal le	[Connecting new K teachers]

Figure 2: Coded analysis of teacher action and responses during professional learning

Theorizing the discrete teacher (un)learning pathways. In this final phase of analysis, the resulting distinct pathways of engagement and learning were connected back to the theoretical foundations of this study (Ravitch & Riggan, 2016). This allowed for a deeper understanding of how and why teachers had responded to the professional learning experience in differential ways. This theoretical understanding then informed the discussion, conclusions, and implications identified through this study.

Findings: Documenting Elementary Teacher (Un)Learning Pathways Towards Anti-racist and Anti-colonial Science Education

In this section, I present the findings of an analysis conducted on teacher cases involved in an extended professional development initiative. The analysis identified distinct teacher learning pathways, each characterized by emblematic patterns of sensemaking, critical-meaning-making, and situated actions throughout the PD and partnership phases. These pathways offer insights

into how teachers engage in (un)learning processes, showcasing variations in transformational consistency and fluctuations between regression and transformation. The aim of delineating these pathways is to provide nuanced understanding into the complexities and possibilities in designing and implementing critical teacher professional learning interventions.

The five pathways of teacher learning discussed below were identified through the patterned responses of multiple educators to the professional learning initiative:

- **The "Non" Performative Settler Pathway:** teachers who exclusively engaged in surface-level, self-serving sensemaking work without critical meaning making nor transformed situated actions. [very common]
- **The Best Intentions Cultural Inclusion Pathway:** teachers who jumped from relatively shallow sensemaking to situated actions that were problematic or shallow without critical meaning making. [very common]
- **The Reluctant Settler Pathway:** teachers who engaged in cycles of significant sensemaking with modest critical meaning making and then engaged in transformative situated actions often only with significant assistance from rogue leadership, plethora of resources over a sustained period of time, ideally years. [moderately common (relative to the duration of PD)]
- **The 'Woke' Co-Conspirator Teacher Pathway:** teachers who enact and embody critical sequences of sensemaking, critical meaning-making and designed situated actions but who are dependent on rogue leadership for accountable action. [rare]
- **The Rogue Settler Diligence Pathway:** Learners along this pathway engage in cycled processes of sensemaking, critical meaning-making with situated action(s). These learners enact and embody settler malleability and settler rigor to push through

destabilization and white discomfort, via a stabilizing orientation of settler responsibility to move forward acts of anti-racist and anti-colonial transformation. [quite rare]

The "Non" Performative Settler Pathway: Shallow Participation That Maintains the Status Quo

Neoliberalism presents itself with multiple deceptive facades, yet it adheres closely to dominant cultural norms. Particularly within the teaching profession, which is significantly influenced by the predominant demographic of white women aligned with white feminisms, neoliberalism adopts a pleasant facade adept at navigating politics of niceties (Castagno, 2019; Vintimilla, 2014). Simultaneously, it upholds the momentum and objectives of the colonial knowledge project (Leonardo, 2018).

This pathway phenomenon is widespread in education, encompassing a significant number of well-meaning yet passive white settlers participating in book clubs, staff meetings, committees, and equity trainings, superficially discussing and contemplating the challenges faced by BIPGM students and communities, or the latest equity strategies without effecting substantive change in dominant instructional practices. Through superficial participation marked by performative ‘non’ performativity, this group depletes resources, contributes to settler battle fatigue among POC often positioned to do the heavy-lifting for settlers (Buena Vista et al., 2021). Such participation reinforces pillars of white supremacy, particularly white innocence and white saviorism and perpetuates shallow engagement without transformative learning, thereby perpetuating the status quo in classrooms and society over successive generations.

This pathway phenomenon is not just theoretical but has practical implications, as observed in the research study where a significant portion of teachers, eight of the twenty-seven,

followed a 'Non' Performative Settler pathway focused solely on sensemaking without meaningful action—as shown in these three case studies.

Case Study 1: Conni's Reductive Sensemaking

Conni, a veteran teacher, initially expressed their participation in the partnership as a means to continue learning and supporting students. However, throughout the PD phases, Conni consistently reverted to reductive sensemaking, maintaining a focus on superficial intentions and niceties rather than engaging in critical meaning-making or active classroom participation. Their statements and actions reflected a pattern of deflecting responsibilities and recentering prior naturalized axioms and status quo maintaining stances, devoid of anti-racist and anti-colonial perspectives or practices.

For example, Conni's re/voicing of ideas from professional development sessions minimized critical themes of anti-racist and anti-colonial (un)learning, reducing them into vague perceptions that upheld dominant epistemic boundaries. This reductive sensemaking was evident in their hope that students would "learn how to see [learning barriers] and learn skills to climb over them or break them down themselves," which deflected their own role as a social actor with settler responsibility. Despite declaring intentions to be more sensitive to students' age, beliefs, and culture, Conni avoided researcher partnership and support, and did not fully engage with extension learning or the Social Focus curriculum.

Throughout the PD arc, Conni consistently derailed discussions with a focus on logistical minutiae rather than critical reflections or transformative actions. Even during core PD sessions on Indigenous Science pedagogies and practices, Conni's statements revealed a pattern of dismissive and reductive sensemaking, centered on settler epistemologies and white innocence. This 'non' performative approach, characterized by deflective and defensive utterances,

ultimately reinforced white supremacy variants within their teaching practices and perpetuated the status quo.

Case Study 2: Calliope's Intermediate Reductive Sensemaking

Calliope engaged in a 'non' performative settler learning pathway marked by sustained and iterative sensemaking. While initially expressing a desire for strategies and feedback, Calliope's sensemaking throughout the PD remained reductive, focusing on gaining knowledge without translating it into meaningful classroom actions. Their participation in PD sessions and equity initiatives validated reductive sensemaking for epistemic competency, without critical reflection on classroom enactment or embodiment of anti-racist practices.

For instance, Calliope's statements during PD sessions and exit tickets demonstrated a pattern of disconnection between critical ideas and classroom practice. Despite verbalizing interest in critical and liberatory presencing, Calliope's sensemaking often reverted to reinforcing systematized instructional practices that contradicted the PD's focus on (un)learning. This disconnect persisted throughout the PD, with Calliope's sensemaking revolving around verbal recitation of content hot takes and recentering of settled instructional practices.

Calliope's journey mirrored that of many 'non' performative settler teachers, showcasing a pattern of reductive sensemaking without critical meaning-making or situated actions in the classroom. Their deceptive participation, characterized by hyper-engagement but lack of transformative learning, highlighted the challenges of addressing systemic inequities within educational contexts.

Case Study 3: Minna's Reflexive Sensemaking and Transformation

The case study of Minna provides an insightful illustration of the potential for change in pedagogical approaches. Minna, whose pseudonym signifies "resolute" and "love," underwent a transformative journey from a 'non' performative settler pathway to a reluctant settler pathway over a 15-month period. This transformation was marked by a progression from sustained sensemaking eventually towards critical meaning-making, showcasing the potential of a commitment to critical inquiry and reflexivity.

Initially, Minna's sensemaking revolved around critical noticing, recognizing the limitations of a restrictive curriculum and the need for inclusivity and expansiveness. They expressed this realization by stating, "I realized I can take a restrictive curriculum and make it more inclusive and expansive - I am still trying to see how to do that within the culture we teach in now." This phase of sensemaking focused on identifying challenges and areas for improvement, demonstrating Minna's evolving awareness of pedagogical possibilities.

As Minna progressed through subsequent phases, their sensemaking evolved into critical inquiries aimed at fostering critical and liberatory presencing in their instruction. For instance, in a phase two PD exit ticket, Minna shared, "I am thinking about how to do more critical liberatory presencing by looking at scientists from all parts of the world, not just tokenism." This shift towards critical liberatory approaches indicated a sense of deeper responsibility with anti-racist and anti-colonial perspectives, signaling potential moves towards critical meaning-making, and situated actions, which could be utilized as key indicators for responsive DBIR PD.

By phase four, Minna's sensemaking had advanced to include actively challenging settler norms and incorporating antiracist and anti-colonial perspectives into their teaching. This transformation was influenced by on-going, consistent practical and reflective experiences within their grade-level team, which often included myself as boundary spanner, demonstrating the

importance of relational influences in settler malleability and transformative learning. Minna's journey involved a progression from critical noticing to critical meaning-making inquiries, eventually leading to a deeper, self-identified, understanding of the embodiment and implications of settler innocence, ignorance, and white saviorism within their teaching practices. This process of destabilizing habits of white supremacy, and stabilizing ambiguity with anti-racist and anti-colonial tenets and actions required time, reflection, and community support. Minna's journey from sustained sensemaking to critical meaning-making and situated action exemplifies the potential for transformative shifts in settler pedagogy, highlighting the need for responsive design of PD learning experiences and ongoing support for educators on 'non' performative settler pathways.

These case studies demonstrate variance of engagement within the 'Non' Performative Settler Pathway, showcasing patterns of sustained sensemaking indicative of settler false consciousness- adherence to pillars of white supremacy despite participation in equity initiatives. This phenomenon underscores the importance of moving beyond performative gestures, symbolic participation towards critically meaningful and responsible engagement and action to dismantle systemic inequities in education.

The Best Intentions Cultural Inclusion Pathway

Teachers following the Cultural Inclusion learning pathway engage in rapid sensemaking, similar to the 'Non' Performative Settler pathway, yet they tend to re-stabilize ambiguity using prior epistemic and ontological naturalized axioms (Phillip, 2011). However, their engagement in classroom instruction and curricular adaptation situated actions sets them apart. This group of teachers filters critical content and practices introduced during the PD partnership through a sensemaking process that leads them back to cultural inclusion instructional methods as the

primary solution for addressing educational inequity. Consequently, they shape their curriculum design and instruction accordingly.

These teachers hold cultural inclusion as their instructional situated actions homeplace, reinforced by their pride in their knowledge of and experiences with various cultures worldwide. Early in phase one, many teachers shared personal experiences such as travels to places like Thailand and Mexico, with one teacher noting, "I have experienced way more than other teachers and this allows me to build upon what we are learning with more personalization." However, this declaration of cultural awareness, coupled with perceptions of themselves as culturally relevant teachers, often solidifies foundations of white arrogance, white innocence, and white saviorism, acting as barriers to transformation.

Case Study 1: Prett's Cultural Inclusion Misappropriation

Prett, a pseudonym meaning trickster, embodies a method of "employing the hook, student culture, and culturally responsive pedagogy [that] is often misappropriated in ways that hoodwink students into engaging with their teacher and the learning process" (Evans et al., 2020, p. 57). This misappropriation, as discussed in "Good Teachers" with "Good Intentions": Misappropriations of Culturally Responsive Pedagogy by Emdin & Adjapong (2018), repackages students/diverse cultures as a product for exchange, promoting adherence to dominant white culture's learning and classroom expectations, ultimately benefiting whiteness and the teacher's whiteness. Derrick Bell (1980) and Milner (2008) postulate this as an incarnation of interest convergence, wherein race and equity issues are addressed only when they align with white ideologies (2020, p. 58). Prett's approach views culture merely as an engagement mechanism or hook, justifying instructionally situated actions that misappropriate culture. For example in phase one Prett proudly shared his inclusion of Indigenous cultures by

having students create Native Tribe dioramas without contextualizing the consequential learning of colonialism and coloniality. Prett's ideological and practical stances continue along this pathway with little transformation which is both evident in his classroom situated actions and participation in PD. This is reflected in Prett's comment during phase three PD on Indigenous science, specifically at a moment when sharing innovative engineering practices in right relations with Land and multispecies kin, Prett asks, "Why did Native Americans choose that feature? Trying to go back and forth between history and science because here's a perfect leeway and I'm fishing with the right bait because students are really into it." Seemingly well-intended within an ideology of white saviorism through diverse inclusion, Prett's actions exemplify white arrogance and maintained white ignorance, thereby bypassing critical meaning-making, thus perpetuating white innocence. This misappropriation of culture serves to assuage white guilt, reinforcing settler false consciousness—an entrenched phenomenon in education that often evades critique or challenge of the prevailing white supremacy culture within educational systems and among educators. Prett's reductive sensemaking of culture and subsequent misappropriation, reflective of other cultural inclusion pioneers, resulted in cultural inclusion mutations, as demonstrated in the shared classroom example.

Case Study 2: Taylor's Tailored Cultural Inclusion

To further analyze how teachers' reductive sensemaking led to cultural mutations along the cultural inclusion pathway, I present the case of Taylor, a pseudonym meaning one who tailors. Taylor, like other educators on this pathway, asserted expertise as a culturally relevant teacher, claiming to tailor all classroom learning to be culturally inclusive. However, Taylor did not consistently engage in critical meaning-making of PD content. During reflection portions of PD sessions, Taylor often highlighted accommodations made for her diverse students, citing their

hardships compared to her white students, such as allowing certain students to knit during science or having lower expectations. While these accommodations may seem tailored to racially diverse students, they are rooted in deficit frames of non-white cultures and lack critical meaning-making to identify why instruction and curriculum fail to serve all students. Taylor's approach also lacked anti-racist and anti-colonial situated actions to disrupt dominant narratives and ideologies and implement liberatory education practices.

Moreover, Taylor's participation in the PD was inconsistent, showing no investment in engaging in the asynchronous learning provided to all TAB teachers through embedded scaffolds for situated action in the course. Taylor's cultural inclusion approach in phase one involved placing students in peer work groups with tribal names to explore how Orcas are impacted by humans. Although Taylor attempted to integrate social justice content, such as discussing pollution and noise affecting Orcas, when prompted to consider how a colonial mindset perpetuates the nature/culture divide, Taylor's defensiveness regarding her knowledge of First Peoples' culture emerged as an expression of white arrogance. This defensiveness was also evident when resistance arose against including the Navy's weapon testing methods in the Ocean, likely due to personal connections to the Navy.

Case Study 3: Maude's Fragmented Cultural Inclusion

Maude, meaning mighty in battle, centers diverse cultures as a source for personal growth but tends to tokenize cultures by focusing on fragmented dimensions without interrogating whiteness and coloniality. Although well-intentioned, Maude's approach lacks critical dimensions necessary for addressing racial oppression and privilege. Inclusion of "The BIPOCS" as cultural and epistemic sources becomes a source for white savior validation, extending to inclusion of multispecies kin but falling into human supremacy narratives outside the adapted curriculum.

Maude's statement reflects her approach: "I put the BIPOCs at the center of my learning as a source for my growth." While this statement is shared with an air of reverence, it is evident that Maude's self-centered focus should be viewed as a mutation of cultural inclusion. Her emphasis on diverse cultures becomes a battleground, a well-meaning mission that holds some value as it edges slightly beyond tokenism towards contextualized inclusion. In the classroom Maude's focus on superficially including diverse perspectives without engaging in deeper critical meaning-making perpetuates a cycle of surface-level diversity evident in her phase three share-out statement that she is "Fusing social studies into Pattern and Sky by including stories about the constellations, moons, stars, universe, etc. Students will learn about how people from all over the world interpret the universe. I want to ensure I am including eastern and First Peoples' perspectives. Would like them to recognize that the same questions they are asking about the sky today were asked by painters, book characters, historians, scientists, people, etc." This approach, while making strides towards inclusivity, falls short of critical liberatory presencing which calls for critically contextualized self-determined representation of BIPGM leaders, knowledge, values and secured futures to disrupt dominant narratives that uphold whiteness and colonial ideologies within the educational framework.

The Reluctant Settler Pathway

Educators traversing this learning pathway exhibit a persistent reluctance to disengage from a sensemaking cycle that offers solace as deracialized individuals inhabiting a realm of perceived participation. Particularly among white women educators, the role of teaching, especially teaching Black, Brown, and Native children, often confers a sense of moral righteousness and personal virtue without the requisite acknowledgment that this perceived merit can inadvertently perpetuate white innocence, ignorance, saviorism, and arrogance. This veil of merit shields

educators from the imperative of engaging in profound axio-ontological, critical meaning-making regarding the educational institution's complicity in systemic racism and the erosion of Indigenous sovereignty. It also encourages educators to view themselves as passive beneficiaries rather than active agents within the system.

The reluctant settler learning pathway expands upon critical settler discourse within the domain of education, exposing how whiteness and feminism intersect to subtly prioritize self-preservation over dismantling oppressive structures. This analysis delves into how white feminism often employs narratives of victimhood to distance itself from the harsh realities of racial and Indigenous oppression, culminating in a "reluctance to acknowledge their role as colonizers" and the consequent realization of the impossibility of achieving a postcolonial state without relinquishing control (Macoun & Strakosch, p. 430). Within the context of our deeply flawed educational system, the reluctant settler narrative legitimizes personal struggles and challenges to minimize their responsibility and agency as a justification for evading meaningful anti-racist and anti-colonial endeavors.

For educators treading the reluctant settler pathway, exemplified by the six white women in this research project, despite evidence of critical meaning-making, for these teachers retreating into sensemaking about best intentions of teaching, standards, schooling and science. This regression pattern became a process of affective desire to disengage from the rigorous work of transformation. With regular patterns of respite from critical meaning-making and reluctance to implement supported situated actions the reluctant settler teacher often sidestepping investment in their own critical settler consciousness trailed behind their 'woke' co-conspirator or diligent rogue settler peers to garner a perception of transformation by proximity absent of personal practical applications. Contrary to the 'non' performative settler who stays situated within

cyclical sensemaking epistemic eddies, the reluctant settler recognizes both the need for liberatory education and their own complacency, akin to wanting to swim in the deep end of the pool to improve their swimming skills yet holding that they could always stay in the shallow end. For the reluctant settler, time, resources and sustained support contributes to the courage needed to dive into deeper waters of transformation.

Case Study 1: Coral's Struggles and Transformations

Coral, a pseudonym selected for its symbolic representation of resilience in the face of adversity, navigated the reluctant settler pathway with a blend of critical inquiry and hesitation towards practical implementation. During phase one of the professional development (PD) program, Coral displayed a commendable engagement in epistemic sensemaking, as evidenced by her query during a PD session: “We do STEAM Day each year. Last year I shared a book about the man who invented the Super Soaker. It seemed like a high-interest topic. The creator is a man of color. The ethnicity of the man was never brought up in our discussion. Was this just a token representation?” Coral’s journey from epistemic sensemaking to critical meaning-making was evident in her evolving understanding of the tokenization of Native American culture in her lessons. In phase two, Coral remarked, “I believe my specified lessons designed to ‘teach about’ Native American culture are tokenizing their culture. It is probably mostly because I don't have enough knowledge about their native culture nor their current culture.” Despite this critical awareness, Coral struggled with the practical application of her insights in her teaching practice. Upon closer examination of Coral’s engagement patterns, it became clear that while she demonstrated a commitment to critical reflection, there was a notable reluctance to translate these insights into actionable changes. This reluctance manifested during grade-level collaboration sessions, where Coral’s apprehensions about the challenges of implementing

change were palpable. Her concerns often circled back to the district's expectations and the potential discomfort of students and families, which hindered progress towards transformative pedagogical approaches.

The disconnect between Coral's critical reflections and her hesitancy to enact change underscored the complexities of the reluctant settler pathway. Despite her deep ideation engagement and meaningful relationships formed during the PD, Coral hesitated to embrace anti-racist and anti-colonial practices fully. This reluctance stemmed from the perceived complexities and challenges associated with such transformative work.

However, as the PD progressed into phase four, particularly after the '*woke*' *co-conspirator* and *rogue settler diligence* pathway teachers shared classroom examples and stories of transformation, Coral began to showcase signs of transformation in her instructional practices. She eagerly shared student artifacts that reflected a shift towards decolonized and liberatory pedagogical approaches. For instance, Coral highlighted a student-developed game inspired by the Puyallup Tribe's efforts to care for the land, animals, and community. This game engaged players in learning about climate change impacts on the wolverine population, demonstrating Coral's evolving commitment to integrating critical liberatory presencing into her curriculum.

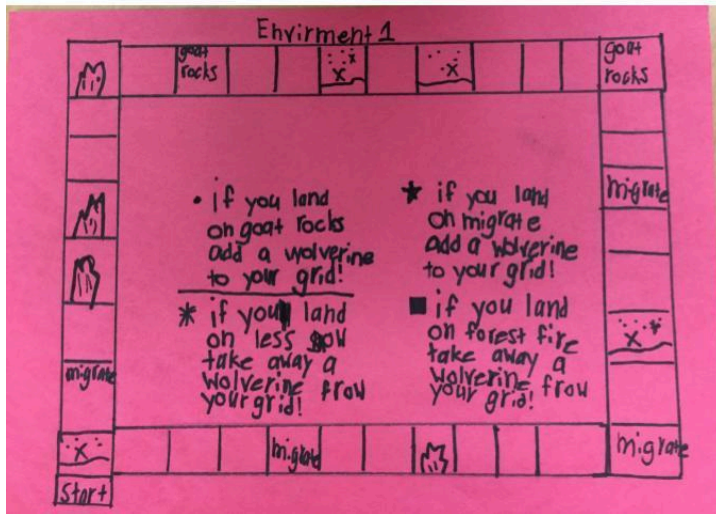


Figure 3: Student game adaptation countering dominant curriculum activity by learning from Puyallup Tribe by centering multispecies well-being, climate change and migration..

Coral’s journey encapsulates the nuanced dynamics of the reluctant settler pathway, where critical reflection coexists with practical challenges and hesitancy towards transformative action. Her trajectory underscores the ongoing process of grappling with pillars of white supremacy, dismantling colonial narratives, and embracing pedagogical practices rooted in anti-racism and anti-coloniality. For DBIR researchers and educators of educators, it is imperative to design for the reluctant settler learner. This design should deeply consider that without the fortification of substrates of support and critical learning over a sustained arc of time, there is a tendency for these learners to fallback into dominant epistemologies and ontologies enabled by the colonial knowledge project that currently defines the education system. But, transformation is possible, when like Patrick Wolfe, who identifies himself as a “reluctant settler” (Kauanui & Wolfe, 2012, p. 237) leverages their settler identity not as a reason to cower away from behind barriers of white ignorance and/or white innocence which invisibilize settlerism and identities, but rather as mere fact, as responsibility and response-ability for action.

Additionally, the reluctant settler benefits greatly from a strong foundation of examples throughout the arc of the PD, provided by prior Social Focus teachers, researched resources and from less reluctant teachers brave enough to take on the messy and rigorous journey of sustained sensemaking, critical meaning-making and situated actions

The 'Woke' Co-Conspirator Teacher Pathway

Early in the partnership, the 'woke' co-conspirator settler teachers surfaced white arrogance coupled with white saviorism as dominant forms of enacted and embodied white supremacy barriers to the liberatory work, veiling white ignorance and white innocence. The settler co-conspirator embarked on their journey with an epistemic ideology rooted in white savior narratives, believing that "to be a good teacher in urban schools, all one needs is leadership abilities, intelligence, and content knowledge, and a desire to make transformational change by working hard" (Kavanagh & Hadley, 2013). Evidence of this orientation was in the pattern of 'woke' pathway teachers' declarations of leadership and knowledge on equitable education reflective in the following teacher quotes, "I have done a lot of equity work", and "[district PDs] feel very beginner." This orientation is emblematic of "neoliberal denial often projected as, 'You're preaching to the choir; I already do/did the work.'" (Ozier, 2023, p. 72)

Each of the teachers on this pathway managed their classrooms as authoritarian teachers, in varying degrees, often flexing their power and presence, to control conversations and inquiry to maintain a pace and trajectory that ensured coverage of standardized content over attending to students' critical questions or divergent thought. This instructional approach was grounded in the false conscious premise that access to dominant knowledge equates to racial and educational equity. This orientation leads to a misconceived notions of equity, teacher responsibility and purpose of schooling.

"For the 'woke' co-conspirator believing in logics of meritocracy perceive knowledge knowledge as currency earned through mastery, with mastery leading to access failing to recognize,"Going to school does not enhance one's chances of success because even if everybody was learning something, schooling is still about stratifying students" (Barton, 2001, p. 848). This onto-axio-epistemic orientation began with teachers attempting to master knowledge presented yet struggled with the destabilizing implications that arose during their critical meaning-making processes. For 'woke' co-conspirator pathway teachers the shock of challenging their own instructional situated actions was often paralyzing, with repeat situated action codes of, *Maintaining dominant pedagogies-(Re)Centering settled*, along with sensemaking codes of, *Teaching requirements often contradict what it means to responsibly take up AR & AC*.

Interestingly, for the 'woke' settler co-conspirators, their own epistemic curiosity (Freire, 2020) and co-conspirator commitments to equitable access, initially demonstrated white arrogance and saviorism— proved to be areas of significant change by taking up settler responsibility in the classroom and settler rigor to wrestle with epistemic collisions for critical meaning-making (Kulago, 2019). This diligence resulted in shifting the focus of science education towards presenting students with the knowledge required for societal integration, rather than fostering their ability to produce, apply, and critically analyze scientific concepts for the purpose of societal transformation.

Case Study 1: Atlas's Rendering of Power for Purpose

Representative of this pathway of transformation and this group of teachers, I elevate the case study of Atlas, pseudonym meaning one with the world on their shoulders. For Atlas, the theory of repurposing education to prioritize students' intellectual health (Bang, 2020) presented in

phase one proved to be a sticky resonance, inspiring new leaps in classroom situated actions, which facilitated transformational critical meaning-making. Early in the partnership Atlas stated, “I’m resonating with the WEIRD dynamic, and really thinking about how white supremacy is embedded in education, down to the curriculum and practices we take for granted.” This overwhelming awareness and Atlas’s sensibilities of holding the weight of the world, albeit perhaps from an orientation of white saviorism, surfaced repetitive pragmatic concerns and tensions about how much work it would take for him to “overhaul” the curriculum. These vital sensemaking platforms also pushed Atlas into unknown territory in the classroom, as part of one of two pathway groups who implemented Social Focus units relatively early, Atlas grappled alongside students with how anti-racist and anti-colonial approaches asserted new ways of thinking about science, engineering, and innovation. For instance, in phase two, one of Atlas’s students asked “What does this have to do with science?” after introducing the Social Focus question, “Who and what should scientists and engineers consider when designing technology”? Atlas leveraged their learning from the third core PD on critical and liberatory presencing which unpacked the intentional and ongoing erasure of BIPGM brilliance and the issues with methods of diverse representation. Atlas admitted: “I think in the past I have relied on tokenization, instead of going into depth, like highlighting Black scientists during Black History Month.” Atlas continued: “Because science doesn’t work all on its own it exists within society and communities.” For Atlas, transformation from a place of equity expertise, to then recognize, and admit in an interview, “I’ve always kind of excluded that stuff from science, kind of feeling like sciences, as its own kind of thing, and not really thinking about the intersection of that with equity, so I think it challenges me personally.” This shift required malleability to rigorously render the comforts of white arrogance. Additionally, Atlas’s white saviorism began to be

transmuted into settler responsibility, which was evident in their statement: “The opposing forces do not let up, not even for a moment - so the fight, whether it starts in a small place like science education, or anywhere else, is vital. This work, with the students, in even just a short time has developed such rich conversations. The kids are ready for the work.” This statement was part of a reminder to themselves to stay diligent to the work of staying ‘woke’, and responsible, continuing to co-conspire with students and others to transform education.

Case Study 2: Jessie's Reflexive Evolution

For Jessie, the journey began with the unsettling of their power in the classroom. Starting from a place where knowledge and execution of equitable education were sources of white arrogance and white saviorism, Jessie seemed to take on the role of a shepherd. Tasked with fervent protection of their students, Jessie worked to shepherd them firmly towards academic success. This stance, evident in their comment, “My kids need me to walk them through every step, I’d like them to do more on their own but that just gets crazy, I even need to do read-alouds for the class. This way I know they are getting the learning in.” This ideology was contrary to their critical sensemaking from phase one about: “Testing, redefining the purpose (evidence to prove your thinking) has gotten away from why learning matters” and their desire to “keep anti-racism at the front of my instruction. It is so easy to get caught up in the day-to-day teaching and I am hoping this helps me take a step back and reflect on what I am actually doing/perpetuating or not perpetuating. Also, how to change it.” This juxtaposition between her stated goals for education relative to her instructional practice seemed to be destabilizing enough that Jessie agreed to partner with myself, my fellow PD co-facilitator (also a graduate researcher at the time), and their grade-level team to pilot the sixth grade Social Focus curriculum, explicitly designed to position students to interrogate the role of colonialism as the global cause of climate change.

Witnessing students leverage science concepts to formulate explanations about a range of climate change phenomena while speculating about their roles and identities as climate justice leaders, proved to be liberating for both the students and Jessie. For Jessie, who began their journey with barriers of white arrogance and white saviorism which, blocked their vision of their own white ignorance and damage-centered moves towards white innocence, shared a reminder to themselves: “Just take time so step away from what you think you are supposed to do and look at your students. Do what is right for them! [Science education] It should create questions that don't have answers and it should cause kids to love our world and planet. This is just really hard. but we can't go backwards, we need to talk about it to move forward! Have fun and teach justice. Go back to the earth!”

Atlas and Jessie, exemplifying teachers traversing this pathway, initially claimed an epistemic state of being 'woke,' based on their participation on race and equity committees and knowledge of racism and social injustice. This orientation of saviorism and arrogance informed their perception of youth and their roles as educators. Destabilization of this ideology resulted in a new echelon of awakening as teachers endeavored to redefine their roles from holders of dominant knowledge to bestow to promote access to and inclusion within the empire to becoming youth allies. Allyship for the ‘woke’ co-conspirator pathway educator aligned with the understanding that “A coconspirator functions as a verb, not a noun” (Love, 2019, p. 17) in the ways classroom situated action centered around nurturing students’ intellectual health by taking up the Social Focus principles of critical consciousness and consequential concern as their settler responsibility. And although teachers along this pathway were both essential exemplars of emergent settler malleability, letting go of their colonial ways of viewing youth as incomplete, (Fikile & Cedillo, 2017) by making strides to desettle science education by implementing

adapted Social Focus units there was little evidence to indicate leadership and action outside of the work completed as a team or outside of the classroom (Picower, 2015). In other words, the ‘woke’ co-conspirator traversed along a pathway cleared and forged by the rogue settler diligence pathways teachers, who’s settler malleability and responsibility and rigorous sensemaking, critical meaning-making and situated action led to more expansive and brave enactments and embodiments of anti-racism and anti-coloniality.

The Rogue Settler Diligence Pathway

Comprising four white female educators, the teachers on the rogue settler diligent learning pathway exemplified a multidimensional commitment to realizing curriculum, classroom, community, and self-transformation. Their dedication to this endeavor was consistent and evident from the early stages of the partnership, providing concrete examples of enacted and embodied evidence that proved essential for the learning of both educators and researchers. The mapping of the settler diligent teachers' pathway highlighted a learning pattern characterized by the engagement with ideological ambiguity and onto-epistemic destabilization. This engagement was facilitated through iterative, cyclical, and progressively rigorous processes of exigent and reflexive sensemaking. These processes were directed towards the cultivation of a radically caring, problem-posing, and critical approach to meaning-making, resulting in the emergence of new affective and onto-epistemic coherences. These coherences were both incited and inciting, spurred on by bold and courageous situated actions.

Within the active spaces of sensemaking, critical meaning-making and situated actions, learning was dependent on and mobilized by rogue settler diligence requiring what can be conceptualized as *settler malleability*, *settler responsibility*, and *settler rigor*. In the following

section I highlight the ways individual teachers exemplified these particular attributes of *rogue settler diligence* (see Fig. 4) within a non-linear learning pattern of sensemaking, critical meaning-making and situated action cycles iteratively, holding that each of these teachers enacted and embodied all three dimensions of the anti-racist and anti-colonial teacher learning model.

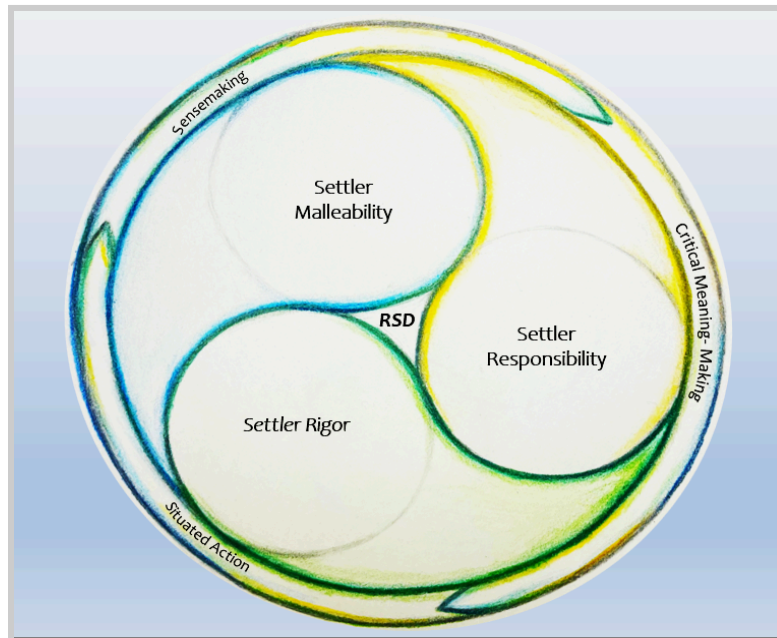


Figure 4: Rogue Settler Diligence attributes and processes framework

Case study 1: Alaura’s Rogue Malleability

For white settler teachers, malleability allowed for exigent reflexive sensemaking, iteratively accepting racial and colonial realism—to move towards considering, as one teacher shared, “how am I an instrument in this agenda and what can I do right now?” This teacher, Alaura, a pseudonym meaning generous, associated with the ever-green Bay Tree, identified as symbolizing courage, exemplified multi-dimensional settler malleability. Alaura, from the beginning of, and beyond, the partnership, leaned into the destabilizing learning of settler coloniality and WEIRD culture, modeling for the entire TAB group how they were connecting

the learning not only to the values they upheld in their classrooms but also as a school leader and within their personal worlds. Alaura's onto-epistemic malleability allowed for exigent reflection about how dominant curriculum is normalized stating, "Our school system is based on WEIRD culture and it limits what we are able to do and accomplish. Rigid System! How does what I choose to teach and how I teach it affect my students? Everything is broken down into subject areas. Subjects seem to be disjointed. There is little integration between subject areas and students' own experiences. Student thinking becomes fractured. There is not much to spark curiosity. There is not as much joy in learning. It is just rote memorization with no clear purpose."

This fluidity of sensemaking towards problem-posing questions for critical meaning-making that occurred early in phase one was maintained and nurtured by Alaura's own initiative to learn and lead change. Later in phase one, like other rogue settler diligent teachers, Alaura eagerly opened up their classroom as a place to pilot lessons as they were being adapted, flexibly accepting the fumbling that would occur in purview to others. For example, during a classroom observation, after sharing "I want to know what I am missing" was prompted to consider how ecosystem hierarchies favor humans, detached from all of Earthly being yet demonizes predators, such as sharks. Alaura, a self-identified white christian woman, openly modeled the rendering of prior ideologies of human supremacy over multispecies as kin, stating "I want help to center interdependence". Alaura's malleability resulted in opening up all science units to consider multispecies kin as vital stakeholders and knowledge holders essential to consequential learning (see Fig. 5).

What can different plants, animals, and communities teach us about how we should respond to climate change for thriving futures?

Stakeholder	Why are they changing?	How are they changing?
Gang gang cockatoo	environment is getting warmer	beaks getting longer
Zebra finch	getting hotter	Conserve energy
Wood mice + Shrew	getting warmer	tails and noses getting longer and legs
snails	Warmer environment	lighter shells
Pizzly Bear	move - because of climate change	coloring new foods
Pink Salmon	water is hotter	migrate earlier and faster
African Elephants	poaching	Absorb CO ₂
Otter	less otters = more sea urchins = less kelp = more CO ₂	predator of sea urchin
tapir	habitat is shrinking	poop out seeds - variety
whales	hunted	poop helps humans and animals

Figure 5: Class generated multispecies classroom stakeholder anchor chart

Additionally, recognizing that as a white settler their anti-racist and anti-colonial comprehension and skills of perception will always be in need of growth (Dei, 2006), Alaura was willing to decenter themselves and dominant knowledge in hopes of countering the erasure of BIPGM expertise and experiences. This began in phase one with her critical noticing: “I have definitely been tokenizing,” bending to own that it is not enough just to know it happens but that it will require diligence to disrupt: “that it's just a constant movement away from tokenism, it's an easy thing to fall into.” Alaura’s malleability led to the understanding that if “I want to decenter myself and white supremacy culture” then “I will be learning alongside students” which at the start of the partnership they admitted, “I am not used to” later embracing it is part of this necessary “messy process.” In an interview Alaura builds on the need to disrupt white epistemic dominance stating students should see the “big picture, the whole picture of [BIPGM] folks doing the work”; she argued that this critical and liberatory presencing of BIPGM within relevant and consequential contexts “should happen across content areas.” This sensemaking and critical meaning making was done in conjunction with classroom instruction; new learning was

immediately applied to the classroom, flexing the curricular agenda and to be critically responsive to student actions. An example of this occurred directly after the PD discussed the ways Land acknowledgments can be tokenizing, with most people not truly understanding the depth of their purpose and meaning. Alaura shared to the entire group that they were supposed to use the Star Spangled Banner for a reading lesson, “And I was like just in the moment I was like, how about I pull up our Land acknowledgment instead, and use that as our text instead of this harmful, not so great song that doesn't necessarily need to be centered. So then, when we discussed an Indigenous astronomer in our science lesson a week later, they were like, oh, so she's part of a Native group that has been there since time immemorial, they just like we're able to jump there and have that deeper understanding across content.” Alaura followed this up by sharing in a conversation following up with her about how anti-racist and anti-colonial teaching happens, “we [white people] can't wait for it to feel good or perfect, we have to just do it, in those moments you see that you should say or do something.”

While Alaura's dedication to a rigorous pathway towards transformation is evident in her conceptual model, especially in her capacity as a teacher partner and within her classroom, it was her malleability—a seemingly consistent trait stemming from an enhanced critical settler consciousness—that catalyzed recognition and led to sustained transformation. This nuanced depiction underscores the ongoing journey of unlearning, growth, and active engagement necessary to dismantle oppressive structures within educational contexts.

Case Study: Mira's Settler Responsibility

While all teachers on a learning pathway of rogue settler diligence demonstrated settler responsibility for this paper, the case study of Mira (pseudonym meaning peaceful ocean) will be shared as representative of (un)learning over the arc of partnership. Mira, one of the less vocal

teacher participants, was a force of transformation, serene on the surface yet dynamically engaged, much like an ocean. While the professional development arc was designed to promote understanding of critical theory as well as support reflection and design opportunities to adopt situated actions that promote liberatory education, Mira did so diligently in ways many other teachers did not. From the start content and discussions about the normalization and pervasiveness of white supremacy culture and colonialism with education was leveraged for exigent reflexive sensemaking and critical meaning-making about society, education, race and equity. Mira shared in an interview that the (un)learning opened up space to consider how “norms of white culture” inform not just science but the entirety of classroom life and challenge how despite “all the things that have happened in our world last couple years” that “white people aren't always thinking about or conscious about helping, just taking” therefore, “what my role is especially as a teacher, a middle class white person. And that's the majority of people in our profession, what does that mean, how can we work to bring light to everybody's voice.” The “critical pedagogy helps me create action by grounding myself in those pieces of it.” This fluid sensemaking and critical meaning-making led to a range of situated actions from pushing back when other grade-level partners channeled colonial deficit logics of children, voicing their reluctance to center the consequentiality of climate change in their third grade unit, stating “I just don't care. It is CLIMATE CHANGE...I won't be able to sleep if I don't teach this.” And stepping up in their school, during the chaos of implementing a new instructional model, managing three instructional assistants while teaching, on average 40 students, to ensure that the Social Focus science units were taught instead of the problematic adopted curriculum. Mira’s ideology of settler responsibility led to further direct action, by recruiting teachers outside the partnership to take up the anti-racist and anti-colonial units. This diligence towards direct action, a flexing of

power in service of justice, as an obligation, despite the ever-present systematic and breathing barriers of transformation, “is really the best and may be the only way to learn what it is to be an accomplice. We’re in a fight, so be ready for confrontation and consequence.”(Carlson-Manathara, 2021, p. 208).

For the rogue settler diligent teachers it was not enough to stay within the parameters of the designed partnership, they took direct action within their situated worlds. Mira, on their own accord, further adapted classroom learning to infuse critical disability theory as counter pedagogy to dominant culture instruction within the context of climate change learning. And while it can be said that Mira and all settler diligent pathway teachers navigated from a place of humility, as indicative in Mira’s statement, “there’s a lot of conversation about equity and equality but I think people often mash them together, I think it [PD] gave me more tools of like how to start creating like justice...I feel like I’ve just barely touched the surface, because this is such a deep rooted issue [whiteness as norm] but I feel just starting at that point means a lot, here's how you can start making that happen for yourself and for your students,” Mira’s settler responsibility, encompasses settler humility while being catalytic, requiring bold and brave direct action to advance transformation, justice and profound radical care (Puig de la Bellacasa, 2017).

Mira, like other rogue settler diligent teachers also came to the visceral understanding that the work of (un)becoming towards anti-racism and anti-coloniality never has “a finish line” but rather is an on-going rigorous, messy journey. Yet, in the words of our next case study: “Once you know better, you do better, you have to.”

Case Study: Alia’s Rogue Settler Rigor

Settler rigor, as a momentous embracing of rogue actions and ideologies, away from white settler shelters of power and comfort, were epitomized in the next and final rogue settler diligence

learning pathway case study. Aila, pseudonym meaning bringer of light and from a strong place, while also exemplifying settler malleability and responsibility, their immediate commitment to (un)learning and transforming their practice and classroom despite facing multitudinous challenges, personally and professionally, never ceased to engage in PD at all levels. Aila's rapid sensemaking of critical content, secured an iterative practice of critical meaning-making about their racial identity in honest, yet not centering ways, stating, "okay I know I am a white woman, but I gotta do my best to not muck things up more, I want to know when I do or say something that is not anti-colonial and antiracist, even if I am just learning about all that, so just tell me." This critical meaning-making fueled the taking on of situated actions above and beyond the timeline of the PD. Aila, not only attended all the whole group and grade-level PD, they invested precious time in all of the corresponding asynchronous learning provided, even bringing that learning directly into the classroom and partnership. For instance, within phase one of the PD, Aila, after watching Leah Penniman's talk *Farming While Black: A Legacy of Innovation and Resistance*, (2018) not only elevated the content into discussion during the third core PD on Critical and Liberatory Presencing but she also partnered with myself to integrate the content into their current science unit—a unit that had yet to be adapted. This resulted in the development of a science unit that centered around seed guardians from Africa and central America which proved to open up communication and relationship building amongst reluctant multilingual students filling the classroom with stories of their familial practices of seed banking and connections to multispecies survival.

Another memorable time of enacted settler rigor was witnessed when I walked into the classroom while students were singing and using co-developed gestures to the song *Stand up for Standing Rock* (Taboo, 2016). This act of critical and liberatory presence of Native communities'

fight to protect Land and Water, was elicited by Aila's rigorous desire and investment to not wait to make change happen, regardless of how messy it might be. Reflective of Sarah Ahmed's sentiment that "It is by showing how we are stuck, by attending to what is habitual and routine in "the what" of the world, that we can keep open the possibility of habit changes, without using that possibility to displace our attention to the present, and without simply wishing for new tricks" (2007, p. 165). The mantra of the messiness of (un)learning anti-racism and anti-coloniality proved to be catalytic, not only for Aila, but other educators, giving a sort of permission to be messy in front of others and even the students. Aila vulnerably shared their "messy" implementation of the seed guardian lessons, "as the plane [unit] was being built" to the collective of teachers, showcasing the realities and actualized application of (un)learning in the classroom. Aila's sense of settler responsibility and rigor, despite the messiness of the journey is woven in their statement that "It's kinda painful to see how I didn't see what I was doing, then to have others watching what I did so they could learn. I guess that's what it takes, it's hard though. It's so messy but I want to know better, more than I care about all the fumbling." This attitude of not waiting for the perfect or even designed moment for implementing change was maintained throughout the partnership, only wavering at one point during family loss, yet never relented.

Although the providing of critical research was modeled by myself and a fellow research assistant/co-facilitator, as a necessary habit for destabilizing dominant cultural knowledge within oneself and content and for the authentic centering of *Othered* voices, it was only the teachers along the rogue settler diligent pathway that endeavored to identify relevant resources promoting anti-racism and anti-coloniality. These included videos, websites and new classroom books aligned to the disciplinary content, yet pushing on disciplinary boundaries. Similar to Alaura and Mira who organized to have new teachers get access to adapted curriculum, even after the

partnership ended, Aila's rigorous commitment to the journey of anti-racist and anti-colonial (un)learning continued within a rogue network space created for the collective as a time to continue to gather and maintain relationships. It was in this space that stories of the messy journey were shared and evidence of pathway shifts continued to unfold. Even more recent, Aila, continuing a settler rigor practice of gifting relevant critical research shared their learning about the genocide in Brazil during a live filming of the play the *Antigone in the Amazon* led by Brazilian and European actors alongside Indigenous activists as an example of a "beautiful collaboration between settlers and Indigenous people."

Theoretical Discussion of the Teacher (Un)Learning Pathways

The five identified teacher (un)learning pathways related to antiracist and anticolonial science teaching represent patterns of engagement of different sets of teachers engaged in the same learning experience. It is useful to consider these patterns of engagement as modes of participation of specific teachers in their extended developmental process related to equity- and justice-centered teaching as it relates to their personal background and social positioning. These patterns of engagement may be stable for individuals across a longer course of their development, or they may directly relate to teacher's developmental capacity to engage in this shared work as it happened. I do not consider these pathways to be essentialized forms of individual engagement, but rather a cross-sectional representation of a set of teachers with different developmental histories, ideological commitments, and forms of community participation. Here I discuss the implications of these five pathways of (un)learning as it relates to the status of current theorizing about such learning processes.

The "Non" Performative Settler Learning Pathway. Teachers in this pathway engaged in surface-level, self-serving sensemaking work without critical meaning making nor

transformed situated actions. Performativity in teacher equity learning is well established in the literature as a presenting problem (Gay & Kirkland, 2003). This often involves revoicing (un)earning in statements that recenter prior stances, knowledge and practices, known as naturalized axioms (Phillip, 2011). Teachers in this pathway often declare the importance of the approach followed by dismissive, reductive sensemaking that recenters settler epistemologies; it is an example of ‘non’performative, “white Diss-course, a speech pattern that has an innocent facade of color-blindness, yet continues to “diss” or disrespect, people of color” (Matias, 2012, p. 132). While the continuous sensemaking pattern of this pathway indicates a sustained ideological rigidity, this research does not assert that those who maintained this mode of sensemaking lack the potential to transition to more transformative pathways. On the contrary, recognizing that teacher learners, especially white teachers, tend to engage in and maintain a pattern of sensemaking opens up opportunities for designing substantive critical meaning-making learning events and situated actions with extended time, scaffolding, and support.

Best Intentions Cultural Inclusion Teacher Learning Pathway. In this pathway teachers jumped from relatively shallow sensemaking efforts to situated actions that were problematic or shallow—without engaging in critical meaning making processes. This kind of superficial response to cultural heterogeneity is common and results in cultural essentialism and stereotyping of cultural communities. A Best Intention Cultural Inclusion Teacher pathway is reflective of a level two additive approach, a dimension of the Transformational Indigenous Praxis Model (TIPM) which expands upon James Banks’s (1989) models of multicultural education and Michael Yellow Bird’s (1998; 2005) research on colonialism and decolonization. The additive approach is when educators “clearly intend to surpass deficit ideologies and see families and communities as knowledge holders, but their social justice frameworks are fragile” (

Pewewardy et.al., 2022, p. 5). Similarly, teachers working along this pathway sought out alternative instructional approaches resulting in instructional cultural misappropriations (Emdin & Adipong, 2018)—rather than the critical liberatory presencing of BIPGM. Evans et. al. (2020) cite Derrick Bell (1980) and Milner (2008) in their postulation that the “repackaging of students’ culture as an incarnation of interest convergence wherein issues of race and equity are only addressed if, and when, they converge with the interests and expectations of white ideologies” (2020, p.58). Within the TIPM research this growth and regression pattern is identified as non-linear, fluid and cyclical wave jumping. By applying an analytical lens of sensemaking, critical meaning-making and situated action as well as critical theory on pillars of white supremacy and settler false consciousness, a finer focus is had to notice deeper patterns within teacher wave jumping which for the best intentions cultural inclusion teachers elevated shallow critical meaning making. For these teachers more robust critical meaning making would have included, as Milner describes a “deep deliberative search to understand their own and other individuals’ racial backgrounds, racial heritage, and consequences of race that cause oppression and privilege” (2003 p. 207). The present work underscores the necessary depth of this work and the need for sustained professional learning and support to take up the work meaningfully.

The Reluctant Settler Teacher Learning Pathway. Research in teacher education underscores the imperative of equipping educators to act as activists and champions of social justice (Apple, 2011; Mutegi, 2022; Picower, 2011). Becoming a critical educator is subtle, long-term work in need of ongoing support for learning, reflexivity, and teaching (McDonough, 2009). In this pathway, teachers engaged in cycles of significant sensemaking with modest to substantial degrees of critical meaning making, however reluctantly took up classroom and curricular situated actions. The reluctance among teachers to adopt critical pedagogies and

integrate critical content into the curriculum often originates from discomfort in moving away from familiar territories of mainstream knowledge and adherence to district protocols. Additionally, white teachers express apprehension about making mistakes due to a lack of critical understanding. As one teacher aptly put it, “how do I do what I don’t know how to do because I’ve been taught not to know what I should know, I don’t know what I don’t know.” This sentiment is a prevalent challenge faced by educators and critical teacher educators (Blimke, et.al., 2014; Jackson et.al. 2016). Furthermore, settler colonial theorists, Macoun and Strakosch (2013) attribute settler reluctance to complex psychological and social dynamics of settlers in postcolonial contexts. Settlers often struggle to acknowledge their role as colonizers and instead adopt alternative identities, such as "colonized subject: settler indigene" or "inheritor of a painful past," to distance themselves from the history of colonization (p. 430). This distancing can be seen as a form of "strategic disavowal" (p. 430), where settlers consciously or unconsciously deny their involvement in the colonizing act.

The complex reasons for settler teachers’ reluctance to take action call to attention the intensity of destabilization that will need to occur for transformation to be set in motion. Radical care of reluctant teachers requires both designing (un)learning to promote destabilization while also providing new grounding to be stabilized upon. This calls for more than “a discrete set of courses and competencies, or an assigned set of experiences, teacher learning is a continuum” (Feiman-Nemser, 2001 as cited by Lyiscott, 2018, p. 247). Professional learning needs to be multifaceted, with documented implementation and examples of anti-racist and anti-colonial situated action, in community over a sustained period of time. Partnerships need to be in place to support that ongoing work.

The 'Woke' Co-Conspirator Teacher Learning Pathway. Teachers on this path enact and embody critical sequences of sensemaking, critical meaning-making and designed situated actions, but they are often dependent on rogue leadership for accountable action in the classroom. The term 'woke' is commonly used to describe a range of attitudes and practices related to equity, diversity, and inclusivity (Ashlee et.al., 2017; Hayes, 2023). The 'woke' co-conspirator while demonstrating commendable progress towards anti-racist and anti-colonial transformation, follows an ideological path of knowing, a project of coming to know by being shown and guided by others leading anti-racist and/or anti-colonial work, most often BIPGM leaders. "Woke-ness has both ontological and axiological components (Babulski, 2020, p. 76)" as was evident with Atlas realization that he must render up his authoritative power as teacher, as holder of dominant knowledge to open his classroom for students to exercise their own agency to grapple with consequential concerns. For Jessie, teaching the Social Focus climate and colonialism unit co-designed by her grade-level team with extensive guidance by Dr. Kelsie Fowler, she came to affectively and epistemically know the power of centering generationally relevant justice in content, destabilizing prior neoliberal beliefs about access to standardized content as equitable education. The 'woke' co-conspirator pathway teachers, through a pattern of sensemaking, situated action then critical meaning-making, to varying degrees took up Altheria Caldera's the woke pedagogical framework distinguishing practices identified as: (a) the use of instructional methods that prioritize critiques of present-day inequities from an intersectional perspective, (b) centering of students' and teachers' lived experiences, and (c) demonstration of activist care (2018, p. 2). While taking up these distinguishing practices is most definitely transformational, and had the partnership not been prematurely foreclosed perhaps woke pedagogical orientation could have advanced to an anti-racist and anti-colonial liberatory

ideological and pedagogical homeplace. However, due to the ways the ‘woke’ co-conspirator entered the partnership from an self-congratulatory (touting participation in race and equity initiatives) and self-pity (consistent codes about practical challenges to enact change, systemically, instructional or curricular) orientation, a pitfall of white teachers (Ozier, 2023). This differed from the rogue settler diligent teachers who engaged from a ideological stance of humility, and desire to become to be more responsible as settlers, thus the ‘woke’ co-conspirator pathway teachers did not substantially engage in curricular development or extensions of anti-racist and anti-colonial (un)learning, maintaining a lock-step behind those “actively involved in anti-oppressive practices aimed at addressing specific inequalities, fostering diversity, or genuinely incorporating marginalized individuals and communities (Babulski, 2020, p. 74).” For the ‘woke’ co-conspirator pathway teachers completion of the partnership meant, an acquisition of critical consciousness compared to rogue settler diligence teachers navigating their participation and pace guided by an ideology, “do this learning for your own healing and liberation, for your community and your children, and for the global community” (Aguilar, 2020, pp. 97–98 as cited by Ozier, 2023).

The Rogue Settler Diligence Teacher Learning Pathway. Teachers along this learning pathway engage in cycled processes of sensemaking, critical meaning-making with situated action(s). They enacted and embodied *settler malleability* and *settler rigor* to push through destabilization and white discomfort, via a stabilizing orientation of *settler responsibility* to move forward acts of anti-racist and anti-colonial transformation. Relatedly, it has been argued that decolonial teacher education that boldly and unapologetically aims to instill and hone practices of critical settler consciousness and rogue settler diligence should be in alignment with Domínguez’s (2017, p. 233) five essential features of liberatory education which include: “(1)

displace colonial epistemologies, and foreground epistemologies reflective of youth and community; (2) engage educators with frameworks of race that capture the dynamic ways in which youth racial and cultural identity is being produced and reimagined; (3) rethink the ways that field experiences position the expertise of educators in relation to youth and community knowledge; (4) actively confront coloniality and create alternative frameworks and identities endowed with hope and possibility; and (5) engage practices that unpack coloniality and explore liberation in the mundane, everyday work of teaching” (quoted in Kulago, 2019, p. 249-250).

In embodying liberatory education features, teachers must exhibit a high degree of malleability to challenge rigid epistemological, ontological and axiological frameworks associated with pillars of white supremacy culture. This shift requires the malleability for rigorous movement away from entrenched patterns that uphold settler logics and ways of being steering towards a horizon characterized by anti-racism and anti-coloniality. This transformative horizon emphasizes ideologies and actions that prioritize the well-being and thriving of communities historically marginalized by systems of power like white supremacy and colonialism. The concept of settler malleability, exemplified by the rogue settler diligent teachers, enables educators to reconsider the purpose of education, emphasizing settler responsibility in securing BIPGM, multispecies kin and LandAirWasterStars futures responsibly (Sanchez, 2023). Rogue settler diligence is grounded in understanding Grace Lee Boggs offers us, “You cannot change any society unless you take responsibility for it, unless you see yourself as belonging to it and responsible for changing it” (Harewood & Keefer, 2009). This forward-looking approach is crucial for embracing critical theory and leveraging ongoing learning processes not just as intentions or best practices, but as acts of reciprocal generosity.

While not all participants adhered strictly to the rigorous diligence embodied by the rogue settler paradigm, the diverse trajectories of each teacher's learning journey provide valuable insights into the (un)learning processes, catalysts, and barriers to ontological-epistemic transformation, as well as the subsequent actions taken within their unique contexts. These diverse pathways serve as guiding indicators for designing professional development that is iterative and adaptable, shedding light on when and how static epistemological frameworks perpetuate surface-level settler perspectives on cultural inclusion. This critique extends to both well-meaning but superficial cultural inclusion strategies and white settler power reifying models that dilute critical theory and transformative practices, lacking depth in meaningful critical engagement. By critically examining these pathways characterized by performative cultural inclusion and lacking substantive critical engagement, we can identify the shortcomings of mainstream DEI models in teacher professional development. These models often reinforce notions of white saviorism, innocence, arrogance, and ignorance, resulting in limited transformative impact. In contrast, pathways marked by reluctant settler engagement and 'woke' co-conspiratorship present intriguing opportunities for exploration in professional development design. These pathways encourage settler educators to adopt rigorous, responsible, and adaptable approaches as catalysts for anti-racist and anti-colonial practices, thereby fostering a transformative educational environment.

Transforming Systems in Support of Teacher Learning Pathways. Leveraging Design-Based Implementation Research (DBIR), the design, development, and implementation of the professional development (PD) aimed to create a range of infrastructured conditions and engagements to support teachers' anti-racist and anti-colonial (un)learning. As Eisenhart and

Finkel (1998) suggest, this was approached as a progressively transformational situated learning model in which participants engage in cultural production along pathways of transformation. The PD was designed to provide opportunities for teachers to take on new identities by “taking on new roles in the learning community, gaining more knowledge, and has access to the discourse, tool use, and more central aspects of participation in the learning community” (Carlone, 2004, p. 396).

This deliberate approach to PD design and implementation contributed to significant growth for all teacher participants, albeit merely at an epistemic level for some, nonetheless, exploration of teacher (un)learning pathways offers valuable insights into the processes of engagement and enactment, contributing to a broader movement toward anti-racist and anti-colonial transformation. Teachers following the Rogue Settler pathway demonstrated a steadfast embrace of the inherent complexity and imperfections in transformation, facilitating the cultivation of critical settler consciousness. Examining how settler responsibility, as a resolute commitment to "know more to do better," regardless of how “messy” transformation is, particularly when it requires stepping beyond white comfort zones and challenging established norms, can steer research objectives towards a collective convergence of interests rather than mere interest convergence. This dedication is crucial for critical learning scientists and proponents of DBIR to better grasp how to design interventions that facilitate sensemaking, critical meaning-making, and situated action thereby mitigating regression, nurturing transformation, and forging a path forward even in the face of potential obstacles like foreclosure.

Having learned from this extensive research I have come to the bittersweet awareness that the original design plan for the arc of the teachers in which teacher participants were

introduced to Indigenous science and pedagogies, anti-coloniality practices and leveraging the above liberatory framework alongside the Social Focus framework earlier in the arc of PD could have proved to be transformational. This would have resulted in the phase 3 content and activities being placed as phase two (un)learning to ensure the partnership and the work was grounded in the promise of anti-racism and anti-coloniality as a shared generative vision and responsibility. To have done so would have shifted research as dirty practice that is violent, transactional, extractive, production-focused methods and aim enforced by people and structures of power unbothered by harm to participants, sacred knowledge, and liberatory purpose (Smith, 2019; Smith, 2005). In doing so the catalytic power of responsibility as a generative engagement reflects Leigh Patel's sentiment that generative responsibility means, "to be in right relation with dynamics of power, history, and futurities we need to be generative, not producing for production's sake" (Tachine & Nicolazzo, 2023, p. xi) could have better been centered as a collective practice of reciprocity. By delaying and derailing the call, made by the university principal investigator, for teachers to produce classroom products before understanding settler responsibilities as outlined in the above liberatory education framework I truly believe more teachers could have made further transformational leaps forward and less regressions into pillars of white supremacy. This remains a systems transformation design hypothesis for future study.

Conclusions & Implications

A liberatory pathway of rogue settler diligence does not promise mastery of anti-racism and anti-coloniality, in fact, it asks on repeat: "Are you willing to take on a lifetime of ambiguity, uncertainty, moral torment? (Waziyatawin, 2009, p. 153). It provides a glimpse into a way forward towards developing "Consent, trust, accountability, and reciprocity are qualities of relationships that are critical for justice-oriented coordination across societal institutions on any

urgent matter. Yet they are precisely the kinds of qualities of relationships that take time to nurture and develop” (Whyte, 2020, p. 2)—attributes necessary for avoiding continued harm against Indigenous peoples, to mitigate a “relational tipping point” (Whyte, 2020) in this case to address climate change and climate injustice. Ultimately as consistent enactments and embodiments teachers committed to a liberatory learning pathway of rogue settler diligence embrace the words of Angela Davis, “You have to act as if it were possible to radically transform the world, And you have to do it all the time” (2014).

It is not enough to provide teachers with PD that aims to massage settler epistemic potentialities to make sense of equity outside the entangled matrix of racism and coloniality in hopes of transformation. Equity, diversity, access, inclusion, or the newest term belonging as entry points for change without critical racial and Indigenous realism along a timeline of historicity and futurities, dangerously and deceptively concretizes white supremacy and coloniality. Honest efforts for liberatory education, particularly during this current era of racial reckoning and climate chaos necessarily need to take up multidimensional, critical DBIR within PD that moves far beyond the nurturing of settler false consciousness, by identifying the complex dimensions of pillars of white supremacy where and as they do and have existed within, structures, systems and ideologies of colonial power, enacted and embodied, not as points of closure, or condemnation, but as locations of healing scorched mindscapes for growing transformation. Transformative anti-racist and anti-colonial professional development requires a critical knowing that onto-axio-epistemic evolution necessarily must engage the whole teacher because “Ideas are always connected to feelings and practice” (Vea, 2023, ISLS closing speech) and (un)learning is, should be, deeply relational and reflective along arcs and pathways with longevity.

And while the current climate for racial justice is tenuous with the attack on the teaching and learning of critical race oriented content, white resistance is not inevitable. For education researchers, teacher educators and learning scientists, mapping the sticky onto-epistemic sites that teachers retreated to, and the naturalized equity axioms educators recentered offers up potential points of designed intervention in order to destabilize the dominant racial ideologies of whiteness (Picower, 2009) and to advance liberatory learning pathways. Designing for such transformation, particularly with white settlers as the leading audience, requires a multidimensional approach that infrastructures sensemaking, critical meaning-making and corresponding situated actions that facilitate shifts in ideation, practice, emotion and relationships in ways that constitute teachers' liberatory pathways of learning towards rogue settler diligence.

Radically caring, multiscaled, network educator PD, sustained over an arc of time, holds immense transformational possibility, yet are precarious endeavors given the pervasiveness and tenacity of racism and colonialism. Given the outcomes of this study, particularly the foreclosure of the teachers' (un)learning, DBIR justice efforts seeking to advance anti-racism and anti-coloniality within a network, as movement building, requires critical infrastructure interventions that proactively design for the ever-looming reality that such efforts are always threatened and far too often strategically stunted—forming *ghost networks* and hauntings of justice and transformation within a network prematurely terminated. Such a critical realist approach to DBIR suggests a hybrid conceptualization of transformational learning that includes the designing, conjecture mapping and infrastructuring planning for *kincentric rogue networking* for continued liberatory pathway making, beyond the inevitable foreclosure of true justice research partnerships that endeavor to dismantle and disrupt. Such an intervention approach

would be proactively designing for the warning James Baldwin offers in his 1963 speech stating, “you must understand that in the attempt to correct so many generations of bad faith and cruelty, when it is operating not only in the classroom but in society, you will meet the most fantastic, the most brutal, and the most determined resistance. There is no point in pretending that this won’t happen.” Critical infrastructuring of PD with radically caring interventions, with varied entry points of (un)learning, along diverging settler pathways for eventual convergence towards rogue settler diligence posits a form of thick solidarity of enacted and embodied settler un-RULE-iness necessary for desettling, dismantling and disrupting white supremacy and colonial logics and agendas within education. Such infrastructuring allows for the implementation of antiracist and anti-colonial education that is sensegiving, meaningful for just future and world making, within the situated possibilities and power of teachers and ultimately students.

References

Adams, J. D., Rahm, J., Kayumova, S., & Brandt, C. (2022). Unpacking “signs of learning” in complex sociopolitical environments. *Mind, Culture, and Activity*, 29(4), 295–300.

<https://doi.org/10.1080/10749039.2023.2185258>

Adams, D. W. (2020). *Education for Extinction: American Indians and the Boarding School Experience, 1875–1928. Revised and Expanded*. University Press of Kansas.

Ahenakew, C. (2016). Grafting indigenous ways of knowing onto non-indigenous ways of being: The (under-estimated) challenges of a decolonial imagination. *International Review of Qualitative Research* (Fall) 9(3), 323–340.

Ahmed, S. (2004). Declarations of whiteness: The non-performativity of anti-racism. *borderlands*, 3(2).

Ahmed, S. (2007). A phenomenology of whiteness. *Feminist Theory*, 8(2), 149-168.
<https://doi.org/10.1177/1464700107078139>

Allen, C. D., & Penuel, W. R. (2015). Studying Teachers' Sensemaking to Investigate Teachers' Responses to Professional Development Focused on New Standards. *Journal of Teacher Education*, 66(2), 136-149. <https://doi.org/10.1177/0022487114560646>

Allen, C. (2020). The Role of Productive Ambiguity in Shaping Teachers' Sensemaking and Implementation of Science Education Reform. In Gresalfi, M. and Horn, I. S. (Eds.), *The Interdisciplinarity of the Learning Sciences, 14th International Conference of the Learning Sciences (ICLS) 2020*, Volume 4 (pp. 1847-1854). Nashville, Tennessee: International Society of the Learning Sciences.

Apple, M. W. (2017). Global crises, social justice, and teacher education. In *Beyond bystanders* (pp. 255-268). Brill.

Arada, K., Sanchez, A., & Bell, P. (2023). Youth as pattern makers for racial justice: How speculative design pedagogy in science can promote restorative futures through radical care practices. *Journal of the Learning Sciences*, 32(1), 76-109.

<https://doi.org/10.1080/10508406.2022.2154158>

Ashlee, A. A., Zamora, B., & Karikari, S. N. (2017). We are woke: A collaborative critical autoethnography of three “womxn” of color graduate students in higher education. *International Journal of Multicultural Education*, 19(1), 89-104.

Aswad, N. G. (2024). Cultivating radical care and otherwise possibilities at the end of the world. *Quarterly Journal of Speech*, 1-7.

Babulski, T. (2020). Being and becoming woke in teacher education. *Phenomenology & Practice*, 14(1), 73-88. DOI: [10.29173/pandpr29399](https://doi.org/10.29173/pandpr29399)

Baldwin, J. (1963). The Negro child—His self-image. *The Saturday Review*, 21.

Bang, M., Marin, A., & Medin, D. (2018). If Indigenous peoples stand with the sciences, will scientists stand with us?. *Daedalus*, 147(2), 148-159.

Bang, M., & Marin, A. (2015). Nature–culture constructs in science learning: Human/non-human agency and intentionality. *Journal of Research in Science Teaching*, 52(4), 530-544. <https://doi.org/10.1002/tea.21204>

Bang, M., & Vossoughi, S. (2016). Participatory design research and educational justice: Studying learning and relations within social change making. *Cognition and instruction*, 34(3), 173-193. DOI: [10.1080/07370008.2016.1181879](https://doi.org/10.1080/07370008.2016.1181879)

Bang, M., Marin, A., & Medin, D. (2018). If Indigenous peoples stand with the sciences, will scientists stand with us?. *Daedalus*, 147(2), 148-159.

Bang, M. (2020). Central Challenge of the 21st Century: Cultivating just, collectively adaptable, sustainable, and culturally thriving communities, *Two Feathers - NAFS*.

Banks, J. A., (1989). Integrating the curriculum with ethnic content: Approaches and guidelines. In J.A. Banks & C.A.M. Banks (Eds.), *Multicultural education: Issues and perspectives* (pp. 189-207). Allyn and Bacon.

Banyacya, T. (1992). The Hopi Message to the United Nations General Assembly. Accessed May, 10, 2009 at <http://banyacya.indigenoustradition.org/un92.html>.

Bell, D. (1991). Racial realism. *Conn. L. Rev.*, 24, 363.

Bell, P. (2019). Infrastructuring Teacher Learning about Equitable Science Instruction. *Journal of Science Teacher Education*, 30(7), 681–690. <https://doi.org/10.1080/1046560X.2019.1668218>

Bell, P., Tzou, C., Bricker, L., & Baines, A. D. (2012). Learning in diversities of structures of

social practice: Accounting for how, why and where people learn science. *Human Development*, 55(5–6), 269–284. <https://doi.org/10.1159/000345315> <https://doi.org/10.1002/tea.21134>

Bell, P. (2004). On the Theoretical Breadth of Design-Based Research in Education. *Educational Psychologist*, 39(4), 243–253. https://doi.org/10.1207/s15326985ep3904_6

Blakeney, A. M. (2005). Antiracist Pedagogy: Definition, Theory, and Professional Development. *Journal of Curriculum and Pedagogy*, 2(1), 119–132. <https://doi.org/10.1080/15505170.2005.10411532>

Blimkie, M. M. F., Vetter, D., & Haig-Brown, C. (2014). Shifting Perspectives and Practices: Teacher Candidates' Experiences of a First Nation, Métis, and Inuit Infusion in Mainstream Teacher Education. *Brock Education Journal*, 23(2). <https://doi.org/10.26522/brocked.v23i2.384>

Aswad, N. G. (2024). Cultivating radical care and otherwise possibilities at the end of the world. *Quarterly Journal of Speech*, 1-7.

Bricker, L. A., & Bell, P. (2014). “What comes to mind when you think of science? The perfumery!”: Documenting science-related cultural learning pathways across contexts and timescales. *Journal of Research in Science Teaching*, 51(3), 260-285.

Brown, Y. (2002). A framework for thinking about racism as an equity issue. Retrieved November 15, 2002 from <http://www.bctf.ca/social/BuildingBridges/support/brown.html>

Caldera, Altheria (2018) "Woke Pedagogy: A Framework for Teaching and Learning," *Diversity, Social Justice, and the Educational Leader*: Vol. 2: No. 3, Article 1.

Available at: <https://scholarworks.uttyler.edu/dsjel/vol2/iss3/1>

Calderon, D. (2014). Uncovering settler grammars in curriculum. *Educational Studies*, 50(4), 313-338.

Carlone, H. B. (2004). The cultural production of science in reform-based physics: Girls' access, participation, and resistance. *Journal of research in science teaching*, 41(4), 392-414.

<https://doi.org/10.1002/tea.20006>

Carlson-Manathara, E. (2021). What Indigenous peoples have asked of us. *Living in Indigenous sovereignty*. Fernwood Publishing.

Cammarota, J. (2011). From hopelessness to hope: Social justice pedagogy in urban education and youth development. *Urban Education*, 46(4), 828-844.

Castagno, A. E. (Ed.). (2019). *The price of nice: How good intentions maintain educational inequity*. U of Minnesota Press.

Corbin, J., & Strauss, A. (2014). *Basics of qualitative research: Techniques and procedures for developing grounded theory*. Sage publications.

Davis, A., Distinguished Professor Emerita, Univ. of Cal., Santa Cruz, Lecture at Southern Illinois University Carbondale (Feb. 13, 2014).

Dei, G. J. S., & Kempf, A. (Eds.). (01 Jan. 2006). *Anti-Colonialism and Education*. Leiden, The Netherlands: Brill. <https://doi.org/10.1163/9789087901110>

Dei, G. J. S. (2008). Indigenous knowledge studies and the next generation: Pedagogical possibilities for anti-colonial education. *The Australian Journal of Indigenous Education*, 37(S1), 5-13.

Del Vecchio, D., Spady, S., & Toomey, N. (2018). Pedagogical Applications of toward What Justice?. In *Toward What Justice?* (pp. 123-146). Routledge.

Denzin, N. K. (1989). *Interpretive biography* (Vol. 17). Sage.

de Oliveira Andreotti, V., Stein, S., Ahenakew, C., & Hunt, D. (2015). Mapping interpretations of decolonization in the context of higher education. *Decolonization: Indigeneity, education & society*, 4(1).

Dreier, O. (2009). Persons in Structures of Social Practice. *Theory & Psychology*, 19(2), 193-212. <https://doi.org/10.1177/0959354309103539>

Dohn, N.B., Hansen, S.B., & Hansen, J.J. (2020). 13 The transfer and transformation of academic literacy in Designing for situated knowledge transformation. Routledge. <https://doi.org/10.4324/9780429275692>

Domínguez, M. (2017). Se hace puentes al andar”: Decolonial teacher education as a needed bridge to culturally sustaining and revitalizing pedagogies. *Culturally sustaining pedagogies: Teaching and learning for justice in a changing world*, 225-246.

Eisenhart, M. A., & Finkel, E. (1998). *Women's science: Learning and succeeding from the margins*. University of Chicago Press.

Emdin, C., & Adjapong, E. S. (Eds.). (2018). # *HipHopEd: The compilation on Hip-hop education: Volume 1: Hip-hop as education, philosophy, and practice* (Vol. 1). Brill.

Erickson, F. (1986). Qualitative methods in research on teaching, In M. Wittrock (Ed.), *Handbook of Research on Teaching*. New York: MacMillan.

Engeström, Y., & Sannino, A. (2021). From mediated actions to heterogenous coalitions: four generations of activity-theoretical studies of work and learning. *Mind, Culture, and Activity*, 28(1), 4-23.

Esposito, L., & Romano, V. (2014). Benevolent Racism: Upholding Racial Inequality in the Name of Black Empowerment. *Western Journal of Black Studies*, 38(2).

Evans, L. M., Turner, C. R., & Allen, K. R. (2020). " Good Teachers" with" Good Intentions": Misappropriations of Culturally Responsive Pedagogy. *Journal of Urban Learning, Teaching, and Research*, 15(1), 51-73.

Fishman, B. J., Penuel, W. R., Allen, A.-R., Cheng, B. H., & Sabelli, N. (2013). Design-Based Implementation Research: An Emerging Model for Transforming the Relationship of Research and Practice. In B. J. Fishman & W. R. Penuel (Eds.), National Society for the Study of Education: Vol 112. Design Based Implementation Research (pp. 136-156).

Freire, P. (1998). *Pedagogy of Freedom. Ethics, democracy, and civic courage*. Rowman &

Littlefield.

Freire, P. (2020). Pedagogy of the oppressed. In *Toward a sociology of education* (pp. 374-386). Routledge

Funes, Y. (2022). Yes, colonialism caused climate change, IPCC Reports. *Atmos*, 4, 2022.

Gay, G., & Kirkland, K. (2003). Developing cultural critical consciousness and self-reflection in preservice teacher education. *Theory into practice*, 42(3), 181-187.

Grande, S. (2003). Whiteman feminism and the colonialist project: A review of contemporary feminist pedagogy and praxis. *Educational theory*, 53(3), 329-346. <https://doi.org/10.1111/j.1741-5446.2003.00329.x>

Grande, S. (2015). *Red pedagogy: Native American social and political thought*. Rowman & Littlefield.

Gorski, P. (2019, April). Avoiding Racial Equity Detours. *Educational Leadership*. ASCD.

Hamad, R. (2020). *White tears/brown scars: How white feminism betrays women of color*. Catapult.

Hambacher, E., & Ginn, K. (2021). Race-visible teacher education: A review of the literature from 2002 to 2018. *Journal of Teacher Education*, 72(3), 329-341.

Harewood, A., & Keefer, T. (2009). Revolution as a new beginning: An interview with Grace Lee Boggs. *Upping The Anti*, 1.

Harjo, L. (2019). *Spiral to the stars: Mvskoke tools of futurity*. University of Arizona Press.

Herrington, J. & Reeves, T.C. (2011). Using design principles to improve pedagogical practice and promote student engagement. In G. Williams, P. Statham, N. Brown & B. Cleland (Eds.), *Changing Demands, Changing Directions. Proceedings ascilite Hobart 2011*. (pp.594-601).

Hayes, C. (2023). To be woke, you must be awake: a critical response to white liberals.

International Journal of Qualitative Studies in Education, 36(8), 1521–1525.

<https://doi.org/10.1080/09518398.2022.2061741>

Hooks, B. (2000). *Feminism is for everybody: Passionate politics*. Pluto Press.

Hooks, B. (2003). *Teaching community: A pedagogy of hope* (Vol. 36). Psychology Press.

Jackson, C., de Beer, J., & White, L. (2016, October). Teachers' affective development during an indigenous knowledge professional teacher intervention. In *Proceedings of the ISTE Conference on Mathematics, Science and Technology Education, Kruger National Park*.

Jackson, A. (2021). Design principles as cultural artifacts: Pedagogical improvisation and the bridging of critical theory and teaching practice. *Mind, Culture, and Activity*, 28(1), 61-81.

Jones, K., & Okun, T. (2001). White supremacy culture. *Dismantling racism: A workbook for social change*.

Jupp, J. C., Leckie, A., Cabrera, N. L., & Utt, J. (2019). Race-Evasive White Teacher Identity Studies 1990–2015: What Can We Learn from 25 Years of Research? *Teachers College Record*, 121(1), 1-58. <https://doi.org/10.1177/016146811912100103>

Kauanui, J. K., & Wolfe, P. (2012). Settler colonialism then and now. A conversation between. *Politica & Società, 1*(2), 235-258.

Kavanagh, K. M., & Dunn, A. H. (2013). Teach for America and the Political Spectacle of Recruiting the "Best and the Brightest". *Critical Education, 4*(11).

Khanmalek, T. "Wild tongues can't be tamed": Rumor, racialized sexuality, and the 1917 Bath Riots in the US-Mexico borderlands. *Lat Stud 19*, 334–357 (2021).

<https://doi.org/10.1057/s41276-021-00324-5>

Kulago, H. A. (2019). In the Business of Futurity: Indigenous Teacher Education & Settler Colonialism. *Equity and Excellence in Education, 52*(2-3), 239-254.

<https://doi.org/10.1080/10665684.2019.1672592>

Ladson-Billings, G. (2021). I'm Here for the Hard Re-Set: Post Pandemic Pedagogy to Preserve Our Culture, *Equity & Excellence in Education, 54*(1), 68-78, DOI:

10.1080/10665684.2020.1863883

Latour, B. (2004). *Politics of nature: How to bring the sciences into democracy* (Catherine Porter, Trans.). Cambridge, MA: Harvard University Press.

Lee, T. S., & McCarty, T. L. (2017). Upholding Indigenous education sovereignty through critical culturally sustaining/revitalizing pedagogy. *Culturally sustaining pedagogies: Teaching and learning for justice in a changing world*, 61-82.

Liboiron, M. (2021). *Pollution is colonialism*. Duke University Press.

Liou, D. D. (2019). Disrupting the Ideology of Settled Expectations: Forging New Social Movements to Dismantle the Educational Racial Contract. *Berkeley Review of Education*, 9(1).
<http://dx.doi.org/10.5070/B89146424>

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge university press. <https://doi.org/10.1017/CBO9780511815355>

Leonardo, Z. (2009). Critical Social Theory: An Introduction. In *Race, Whiteness, and Education* (pp. 13-26). Routledge.

Leonardo, Z. (2013). Pale/ontology: The status of whiteness in education. In *Educational Inequalities* (pp. 23-40). Routledge.

Leonardo, Z., & Grubb, W. N. (2018). *Education and racism: A primer on issues and dilemmas*. Routledge.

Leonardo, Z. (2018). Dis-orienting Western knowledge: Coloniality, curriculum and crisis. *The Cambridge Journal of Anthropology*, 36(2), 7-20.

Liboiron, M. (2021). *Pollution is colonialism*. Duke University Press.

Lofland, J., & Lofland, L. H. (1995). Developing analysis. *Analyzing social setting*, 183-203.

Lyiscott, J. J., Caraballo, L., & Morrell, E. (2018). An anticolonial framework for urban teacher preparation. *The New Educator*, 14(3), 231-251.

Macoun, A., & Strakosch, E. (2013). The ethical demands of settler colonial theory. *Settler Colonial Studies*, 3(3-4), 426-443.

Madkins TC, de Royston MM. (2019). Illuminating political clarity in culturally relevant science instruction. *Science Education*, 103(6), 1319-1346. doi: 10.1002/sce.21542. Epub 2019 Jul 31. PMID: 37868331; PMCID: PMC10588766.

Maldonado-Torres, N. (2007). On the coloniality of being: Contributions to the development of a concept. *Cultural studies*, 21(2-3), 240-270. <https://doi.org/10.1080/09502380601162548>

Matias, C. E., & Boucher, C. (2023). From critical whiteness studies to a critical study of whiteness: Restoring criticality in critical whiteness studies. *Whiteness and Education*, 8(1), 64-81. DOI: [10.1080/23793406.2021.1993751](https://doi.org/10.1080/23793406.2021.1993751)

McDonough, K. (2009). Pathways to Critical Consciousness: A First-Year Teacher's Engagement With Issues of Race and Equity. *Journal of Teacher Education*, 60(5), 528-537. <https://doi-org.offcampus.lib.washington.edu/10.1177/0022487109348594>

McLaughlin, M.W., Mitra, D. Theory-based Change and Change-based Theory: Going Deeper, Going Broader. *Journal of Educational Change*, 2, 301–323 (2001).

<https://doi.org/10.1023/A:1014616908334>

McLeod, M. (1998). There's no place to go but up. *bell hooks and Maya Angelou in conversation. Lion's Roar: Buddhist Wisdom for our Time. Winter.*

Meixi, Moreno-Dulcey, F., Alcalá, L., Keyser, U., & Elliott-Groves, E. (2022). When learning is life giving: Redesigning schools with indigenous systems of relationality. *AERA Open*, 8, 23328584211062587.

Mensah, F. M. (2019). Finding voice and passion: Critical race theory methodology in science teacher education. *American Educational Research Journal*, 56(4), 1412-1456.

<https://doi.org/10.3102/0002831218818093>

Mills, C. W. (1997). Carnal Knowledges: Beyond Rawls and Sandel. In S. Brennan, T. Isaacs, & M. Milde (Eds.), *A Question of Values: New Canadian Perspectives in Ethics and Political Philosophy* (pp. 155-174). Rodopi Press.

Mills, C. W. (2007). White ignorance. In S. Sullivan & N. Tuana(Eds.), *Race and epistemologies of ignorance* (pp. 13–38). New York, NY: SUNY Press

Milner, H. R. (2008). Critical Race Theory and Interest Convergence as Analytic Tools in Teacher Education Policies and Practices. *Journal of Teacher Education*, 59(4), 332-346.

<https://doi.org/10.1177/0022487108321884>

Milner, H. R. (2008). Critical Race Theory and Interest Convergence as Analytic Tools in Teacher Education Policies and Practices. *Journal of Teacher Education*, 59(4), 332-346. <https://doi.org/10.1177/0022487108321884>

Morales-Doyle, D. (2017). Justice-centered science pedagogy: A catalyst for academic achievement and social transformation. *Science Education*, 101(6), 1034-1060.

Mutegi, J. W., Smith-Mutegi, D., & Lewis, N. (2022). Fostering critical perspectives of science among preservice elementary teachers: An empirical identification of affordances and hindrances. *Journal of Science Teacher Education*, 33(8), 888-909.

Nasir, N.S., Lee, C.D., Pea, R., & McKinney de Royston, M. (Eds.). (2020). *Handbook of the Cultural Foundations of Learning* (1st ed.). Routledge. <https://doi.org/10.4324/9780203774977>

Nxumalo, F. (2021). Disrupting anti-Blackness in early childhood qualitative inquiry: Thinking with Black refusal and Black futurity. *Qualitative Inquiry*, 27(10), 1191-1199.

Nxumalo, F., & Cedillo, S. (2017). Decolonizing place in early childhood studies: Thinking with Indigenous onto-epistemologies and Black feminist geographies. *Global studies of childhood*, 7(2), 99-112.

Ozier, L. W. (2023). Dear White Teachers: What Are We Waiting For?. In *From Being Woke to Doing #theWork* (pp. 69-82). Brill.

Patterson, A., & Gray, S. (2019). Teaching to Transform: (W)holistic Science Pedagogy. *Theory Into Practice*, 58(4), 328–337. <https://doi.org/10.1080/00405841.2019.1626616>

Penniman, L., (2018, December 6) *38th Annual E. F. Schumacher Lectures: Farming While Black: A Legacy of Innovation and Resistance*. [Video] YouTube <https://www.youtube.com/watch?v=gw6eG1rQapo>

Penuel, W. R., Fishman, B. J., Cheng, B. H., & Sabelli, N. (2011). Organizing research and development at the intersection of learning, implementation, and design. *Educational Researcher*, 40(7), 331-337. DOI: 10.3102/0013189X11421826

Pewewardy, C. D., Lees, A., & Clark-Shim, H. (2018). The transformational Indigenous praxis model: Stages for developing critical consciousness in Indigenous education. *Wicazo Sa Review*, 33(1), 38-69.

Pewewardy, C., & Lees, A. (Eds.). (2022). *Unsettling settler-colonial education: The transformational Indigenous praxis model*. Teachers College Press.

Philip, T. M. (2019). Principled Improvisation to Support Novice Teacher Learning. *Teachers College Record*, 121(6), 1-32. <https://doi.org/10.1177/016146811912100607>

Picower, B. (2011). Resisting compliance: Learning to teach for social justice in a neoliberal context. *Teachers College Record*, 113(5), 1105-1134.

Picower, B. (2015). Nothing about us without us: Teacher-driven critical professional development. *Radical Pedagogy*, 12(1), 1-26.

Pinar, W. F. (2004). *What is curriculum theory?* Mahwah, NJ: Lawrence Erlbaum Associates.

Philip, T. M. (2011). An “ideology in pieces” approach to studying change in teachers’ sense-making about race, racism, and racial justice. *Cognition & Instruction*, 29(3), 297–329. doi:10.1080/07370008.2011.583369

Philip, T. M., Bang, M., & Jackson, K. (2018). Articulating the “how,” the “for what,” the “for whom,” and the “with whom” in concert: A call to broaden the benchmarks of our scholarship. *Cognition and Instruction*, 36(2), 83-88.

Pugh, P., McGinty, M., & Bang, M. (2019). Relational epistemologies in land-based learning environments: reasoning about ecological systems and spatial indexing in motion. *Cultural Studies of Science Education*, 14, 425-448.

Ravitch, S. M., & Riggan, M. (2016). *Reason & rigor: How conceptual frameworks guide research*. Sage Publications.

Rivera-McCutchen, R. L. (2021). “We Don’t Got Time for Grumbling”: Toward an Ethic of Radical Care in Urban School Leadership. *Educational Administration Quarterly*, 57(2), 257-289. <https://doi.org/10.1177/0013161X20925892>

Sabzalian, L. (2019). *Indigenous children’s survivance in public schools*. Routledge. <https://doi.org/10.4324/9780429427503>

Sanchez, A. Just worlding design principles: childrens’ multispecies and radical care priorities in science and engineering education. *Cult Stud of Sci Educ* 18, 1041–1069 (2023). <https://doi.org/10.1007/s11422-023-10197-w>

Sanchez, A. (2024). The Social Focus Framework: Antiracist and Anticolonial Conscientization, Consequence, and Presencing in Science Education. In: Tolbert, S., Wallace, M.F., Higgins, M., Bazzul, J. (eds.), *Reimagining Science Education in the Anthropocene, Volume 2*. Palgrave Studies in Education and the Environment. Palgrave Macmillan, Cham.

https://doi.org/10.1007/978-3-031-35430-4_8

Said, E. W. (2012). *Culture and imperialism*. Vintage.

Shah, N. (2021). Racial equity and justice in teaching and teacher education: Progress, tensions, and open questions. *A White Paper Written for the Spencer Foundation*. Chicago, IL: Spencer Foundation.

Shah, N. (in review) Beyond Awareness and Understanding: A Framework for Anti-racism Learning in Practice. *Educational Researcher*

Simpson, L. (2014). Land as pedagogy: Nishnaabeg intelligence and rebellious transformation. *Decolonization: Indigeneity, Education & Society*, 3(3), 1–25.

Sleeter, C. & Bernal, D. (2002). *Critical pedagogy, critical race theory, and antiracist education: Implications for multicultural education*.

Smith, L. T. (1999). *Decolonizing methodologies: research and indigenous peoples*. New York: St.

Smith, L. T. (2005). Building a research agenda for indigenous epistemologies and education. *Anthropology & education quarterly*, 36(1), 93-95.

Stromholt, S., & Bell, P. (2018). Designing for expansive science learning and identification across settings. *Cultural Studies of Science Education*, 13(4), 1015-1047.

Styres, S. (2019). Literacies of Land: Decolonizing narratives, storying, and literature. In L. T. Smith, E. Tuck, & K. W. Yang (Eds.), *Indigenous and decolonizing studies in education: Mapping the long view* (pp. 24–37). Routledge.

Suzuki, David. (2022). *The sacred balance: Rediscovering our place in nature*. Greystone Books Ltd.

Taboo (2016, December 4) *Stand up/Standing Rock*. [Video] YouTube.
<https://www.youtube.com/watch?v=Onyk7guvHK8>

Tachine, A., & Nicolazzo, Z. (Eds.). (2023). *Weaving an otherwise: In-relations methodological practice*. Taylor & Francis.

Takaki, R. (2012). *A different mirror: A history of multicultural America (Revised edition)*. eBookIt. com.

Tuck, E. (2009). Suspending damage: A letter to communities. *Harvard educational review*, 79(3), 409-428.

Tuck, E., & Gaztambide-Fernández, R. A. (2013). Curriculum, replacement, and settler futurity. *Journal of Curriculum Theorizing*, 29(1), 72–89.

Tuck, E., & Yang, K. W. (2018). Toward what justice. *Describing diverse dreams of justice in education*.

Vaught, S., & Castagno, A. (2008). “I don’t think I’m a racist”: Critical race theory, teacher attitudes, and structural racism. *Race, Ethnicity, and Education*, 11, 95–113.

doi:10.1080/13613320802110217.

Vea, (2023, June 15). International Society of the Learning Sciences closing ceremony [Conference presentation]. ISLS Annual Meeting, Montreal, Canada.

Vintimilla, C. (2014). Neoliberal fun and happiness in early childhood education. *Journal of Childhood Studies*, 79-87.

Vygotsky, L. S. (1978). *Mind in Society: The Development of Higher Psychological Processes*. Cambridge, MA: Harvard University Press.

Waterman, R. H. (1990). *Adhocracy*. WW Norton & Company. ISBN 10: 0393310841

Warren, B., Vossoughi, S., Rosebery, A. S., Bang, M., & Taylor, E. V. (2020). Multiple ways of knowing*: Re-imagining disciplinary learning. In *Handbook of the cultural foundations of learning* (pp. 277-294). Routledge.

Waziyatawin. (2009). You can’t un-ring a bell: Demonstrating contrition through action. In G. Younging, J. Dewar, & M. DeGagne (Eds.), *Response, responsibility, and renewal: Canada’s*

truth and reconciliation journey (pp. 191-202). Retrieved from <http://www.ahf.ca/downloads/trc2.pdf>

Wildcat, M., McDonald, M., Irlbacher-Fox, S., & Coulthard, G. (2014). Learning from the Land: Indigenous Land-based pedagogy and decolonization. *Decolonization: Indigeneity, Education & Society*, 3(3), I–XV.

Wolfe, P. (2006). Settler colonialism and the elimination of the native. *Journal of Genocide Research*, 8(4), 387–409. <https://doi.org/10.1080/14623520601056240>

Whyte, K. P. (2013). Justice forward: Tribes, climate adaptation and responsibility. In *Climate change and indigenous peoples in the United States: Impacts, experiences and actions* (pp. 9-22). Cham: Springer International Publishing.

Whyte, K. (2020). Too late for indigenous climate justice: Ecological and relational tipping points. *Wiley Interdisciplinary Reviews: Climate Change*, 11(1), e603.

Yellow Bird, M. (1998). *A model of the effects of colonialism*. Office for the Study of Indigenous Social and Cultural Justice.

Yellow bird, M. (2005). Tribal critical thinking centers. In W.A Wilson & M. Yellow Bird (Eds) *For Indigenous eyes only: A decolonization handbook* (pp. 9-29). School for Advanced Research Press.

CHAPTER 3:

Disrupting white Geology in Science Education by Centering the Eco-Relational Mattering of Consequential Lands: A Second Grade Student Case Study of Possibility

Introduction

Dominant science education practices in geology, a pivotal field within the Earth sciences, employ a Cartesian-influenced, reductionist method of instruction, aiming to achieve a veneer of universality and neutrality while detaching the parts of land from the whole of Land² (Pierotti & Wildcat, 2000). This approach lacks consideration for the complex socio-ecological histories and the pressing matters that impact rightful relationships between LandAirWaterStars and multispecies kin (Sanchez, 2023). In its enduring form, formal geology education has operated within rigid confines characterized by *white geology* which “creates atemporal materiality dislocated from place and time—a mythology of disassociation in the formation of matter independent of its languages of description and the historical constitution of its social relations” (Yusoff, 2018, p.14). This education often overlooks the critical historicities and enduring patterns of Indigenous genocide, slavery, and settler colonialism through a structure of extraction and erasure that is indifferent to the specifics of people and places. As a result, students are steered along epistemic pathways that perpetuate settler colonialism and erase culturally and racially lived, and living, storied realities with, on, and because of Land.

² Aligned with scholars like Sandra Styres and Max Liboiron, I follow the practice of capitalizing "Land" when referring to it as “unique entity that is the combined living spirit of plants, animals, air, water, humans, histories, and events recognized by many Indigenous communities” (Liboiron, 2021, p.7). This practice extends to other Earthly entities, including Water, River, and Salmon, emphasizing their sacredness. Conversely, terms like "white," which reinforce dominant cultural norms or colonization, are written in lowercase. Similarly, I capitalize "Indigenous" and "Native" to recognize their cultural significance.

Coupled with this Euro-westernized Landless, affect-less, zero-point (Warren et. al., 2020) approach to geology that dissects lived and living consequentiality from learning, the siloing of the sciences from the sciences, as separate “glass-encased shiny epistemological objects” (Higgins & Sanchez, in review, p.1) and hierarchical ranking of the sciences has relegated Earth science as a low priority science field of study and instruction, with geology at the bottom and geography as a distant disciplinary domain (Vasconcelos & Orion, 2021; Orion, 2019). Although it has been clearly established that the decentering of Land within science has been to settle science to further colonial agendas of progress that normalize the uncare of land for extraction and exploitation (Bang, et al., 2022; Whyte, 2020), the way Earth sciences have been dismissed by mainstream education can also be attributed to the ingested and ingrained neoliberal ideology among educators that inclusion of science content into their instruction is only for purposes of promoting a future workforce—often as an attempt for equity—which is a harmful premise that coddles settler false consciousness (Kulago, 2019) and, in fact, exacerbates educational injustice (Strong, et al., 2016).

In elementary science, students often learn to memorize types of landforms and their changes over time through abstract illustrations, without connecting these to the consequential geographies where landforms have been altered by mining, overdevelopment, and climate change. These educational practices displace and erase Indigenous peoples and vital multispecies kin, from Cryptobiotic Soil to River Dolphins, fostering generations of students who are disconnected from the deeper, relational understandings of their environments. This reductive siloing and the Euro-westernized, Landless approach to geology education dissect lived and living consequentiality from learning and treat the sciences as separate, compartmentalized

fields, effectively relegating Earth science to a low priority (Vasconcelos & Orion, 2021; Orion, 2019).

A central theme and purpose of this research is to offer critical pedagogical possibilities to disrupt white geology through the adoption of transdisciplinary instruction and learning as a method for anti-racist and anti-colonial science education. This approach challenges the traditional siloing within education and positions geology not only within the realm of Earth sciences but across all scientific disciplines. Such integration is crucial for addressing the reductive and disconnected nature of current education systems, especially in the context of climate change education, which is often paralyzed by politics, adult fears, and abstract, standardized facts that are distanced from other areas of scientific learning.

By disrupting the entrenched narratives of white geology and interweaving the consequential matters of Land and the eco-relational significance of these connections, educators and learners can foster a more expansive cross-disciplinary dialogue. This is essential for transforming science education into an endeavor of radical care in these socio-ecological precarious times. Transdisciplinary approaches not only bridge the gaps created by traditional educational models but also highlight the interconnectedness of various scientific disciplines along with other knowledge systems, allowing for a more holistic and integrated understanding of our world (Warren, et al., 2020). This shift is not just educational but deeply political, aiming to cultivate and nurture students' socio-ecological caring identities as guardians of the Land, and confront the challenges posed by climate change and colonial legacies.

But can such an approach surface and refine the relational thinking of young children with our multispecies kin? And if so, what does that relational learning and thinking look like? This research seeks to disrupt settler colonial geo-imaginaries and re-envision science education

as a space for critical, liberatory engagement with the world. By prioritizing transdisciplinary learning and focusing on the mattering of consequential concerns, this approach advocates for a science education that is not only about knowledge acquisition, but about fostering a deep sense of care and responsibility towards our planet and each other. With this purpose in mind and heart this research aims to address the following specific questions:

- What are the possibilities for disrupting settler colonial geo-imaginaries and cultivating second-grade students' socio-ecological caring and relational reasoning as Land Guardians?
- What are the implications of this socio-ecological caring and relational reasoning by second-grade students for anti-racist and anti-colonial science pedagogy?

Theoretical Foundations: Making Space for the Mattering of Consequential Concerns

To make matter that which dominant culture has made matter-less would mean making significant and necessary the consequential concerns of BIPGM and Othered Earthly kin alongside dominant “stories that have been circulated” to affectively and critically grapple with and speculate about potential pathways of futurity or further extinction(s). By doing so, we can re-purpose settled science and geology in ways that expand the fields as vital inquiry spaces to explore, nurture and radically care for essential eco-relations and eco-relational matters thereby disrupting paradigms of colonial power.

However, a significant challenge emerges as the majority of science educators, primarily white settlers, have been slow to respond to the urgent need for a fundamental rethink, and restructuring of curriculum and teaching methods. This inertia persists despite the mounting evidence of climate change and the pressing injustices faced by BIPGM and multispecies

communities, both locally and globally. Consequently, science education, including geology education, often remains ideologically neutral if it is taught at all.

While it may be argued that there have been attempts to incorporate content related to social justice and climate change into the curriculum, these efforts are often superficial and can be seen as misleading, only serving to placate teachers' misconceptions. For example, recent efforts related to climate change typically focus on a single, though thought-provoking, phenomenon, without addressing or challenging the socio-political and colonial factors underlying climate change. This approach fails to acknowledge the complex web of socio-ecological relationships that demand more profound attention and care.

When it comes to justice-centered topics in science education, many continue to prioritize standardized content rooted in Western knowledge, relegating justice topics, particularly environmental justice, to a secondary position in the curriculum. This practice reinforces narratives of suffering for BIPGM (Tuck, 2009; Zeidler, 2016) and normalizes whiteness as an ideal. While some sensational aspects of science are included in Westernized curriculum, they often fail to give rise to transformative thinking or meaningful change.

To truly transform formal science and geology education, it is essential to move away from damage-centered social justice approaches and simplistic, justice-neutral approaches that focus on superficially "cool phenomena." Instead, learning should revolve around substantive engagement with anti-racist and anti-colonial concerns. Countering dominant white geology, which takes up reductive zero-epistemological approaches to instruction, requires teachers to shift their roles as distributors of banked right answers to critically responsible educators.

(Kayumova & Tippins, 2021) This shift in perspective aims to disrupt existing paradigms within science and geology education. The Social Focus Framework (Sanchez, 2023) which centers

principles of critical consciousness, consequential concern and critical liberatory presence was utilized to guide the professional development and curricular development work of this research practice partnership. This classroom case study, while attending to all three principles, has a particular emphasis on the principle of consequential concern as method of disruption, countering and critical responsibility. By creating space for and prioritizing consequential socio-ecological and socio-political issues that are deeply intertwined with the Land, geology and science come to matter multidimensionally. The three dimensions of consequential concern proposed by the Social Focus framework are defined as:

Matters of Justice & Cultural Significance- Science learning is designed to investigate contextualized issues of consequence that threaten non-white communities' rights, cultural ways of knowing by addressing systemic oppression and white supremacy which limits access to resources, power, and physical & ecological security & well-being.

Matters of Relational & Collective Wellbeing- Science learning disrupts westernized dominant paradigms, narratives & practices of science that depoliticize science learning and promote human supremacy. Content moves beyond reductive "science for science's sake" furthering white progress narratives & traits and calls for critical responsibility and reciprocity. Teaching centers Anti-racist and Anti-colonial counter narratives & methodologies of science that are relational, interconnected, for collective thriving.

Matters of Futurity & Ecological Caring- Topics have social gravity as they position students to make connections between science content and the conditions and consequential concerns facing society. Aims to be generationally relevant and future leaning by investigating topics that have significant impacts on the future well-being of society, ecosystems, and marginalized communities & cultures.

By transcending the notions of neutrality and pursuing science solely for its own sake, we open up space within science and geology education to embrace transdisciplinary content and approaches as moves towards becoming anti-empire (Mckittrick, 2021). An essential aspect of this transformation is the identification and elimination of artificial barriers that have traditionally separated different fields of knowledge. This process acknowledges that "transdisciplinary approaches provide a solution to the deficit model, which tends to prioritize knowledge from European/Western societies, and instead promotes transformational learning" (Newberry & Trujillo, 2018, p. 206). Furthermore, it's crucial to recognize the intricate interconnectedness of the sciences. Geology, for example, occurs within and interacts with various geographies, weaving critical historical narratives. Meanwhile, life sciences and chemistry play out on the stage of physics, creating a dynamic playground of interdisciplinary exploration.

Transdisciplinary "true learning" which according to Cajete (2005) incorporates technical knowledge as well as an emphasis on "reciprocal relationships with both human and natural communities" (Newberry & Trujillo, 2018, p.204) provides the pedagogical substance needed for a form of consequential and expansive science education (Stromholt & Bell, 2018). By weaving transdisciplinary content and critical approaches to literacies of Land, as an "articulation of ancient knowledges grounded in the experiences of self-in-relationship to place" it supports engaging students "to actively analyze and engage with meaning-making through a variety of texts, media, and popular culture looking for and exploring underlying messages and symbolic representations" (Styres, 2018 p.25). This allows them "to make connections between different types and forms for knowledge and allow them to examine concepts of culture, knowledge and power through an Indigenous lens, which in turn promotes self-education and

sovereignty (Brayboy, 2006)” (Newberry & Trujillo, 2018, p. 212) In doing so, an emergent curriculum unfolds, opening up expansive opportunities for teachers to and students to collectively vision and champion a new educational *Otherwise*, critically aware of socio-ecological complexities and vulnerabilities in an era of climate colonialism.

For the present study, I will be leveraging the Relational Epistemologies Framework developed by Bang, et. al. (2018) to provide a foundation of Indigenous science in hopes of promoting critical epistemic heterogeneity within science education and for science educators and students to better “become champions of the common good and adequately respond to contemporary problems (p. 151). The Relational Epistemologies Framework (REF; Bang et.al., 2018) consists of the following dimensions:

1. view humans as a part of the natural world, rather than apart from it;
2. attend to and value the interdependencies that compose the natural world;
3. attend to the roles actors play in expanded notions of ecosystems from assumptions of contribution and purpose, rather than assumptions of competition;
4. focus on whole organisms and systems at the macroscopic level of human perception (also a signature of complex-systems theory);
5. see all life forms as agentic, having person-hood and communicative capacity (as distinct from anthropocentrism);
6. adopt multiple perspectives, including interspecies perspectives, in thought and action; and
7. weigh the impacts and responsibilities of knowledge toward action.

The REF is centered as an analytical lens within this research to better understand “what relational epistemologies look like in the context of knowledge and reasoning” (Bang, et al., 2018, p. 152) for student learning and teacher instruction. The REF dimensions leaning towards anti-racism ground the case study analysis in the ways they, “suggests patterned cultural differences in ways of looking at and making sense of the world” (p. 151-152) rarely taken up comprehensively by westernized science in “a coherent and intentional way.” (p.151-152)

Methods

Setting and Participants

For this NSF-funded research practice partnership project, the research focused exclusively on educators within a suburban school district network, spanning 15 elementary schools in the Pacific Northwest. In the overall study, 27 elementary school teachers from a mid-sized city in the Pacific Northwest participated in 15 months of professional learning and collaborative curriculum adaptation. In overlapping and extending ways, the teachers then enacted those adapted lessons in their elementary classrooms with students. Student-level data was collected from 4 of the second grade teachers. Given the purpose of this paper—to show how young children—can be supported to engage in relational thinking in support of multispecies justice and flourishing—one teacher’s second-grade classroom was selected. The focal teacher, Ammarah, a pseudonym meaning steadfast and strong, was the only teacher of Color in the 15-month study and engaged in learning, curriculum design, and enactment as a rogue diligent teacher (see Chapter 2). I attended the final public presentation of her student’s projects and selected one student to be the focus of this learner case study. Kai was selected for this analysis because he was able to verbally describe his thinking with a greater depth than some of his peers. He was selected because he provides a rich, strong case of the kind of relational thinking that was possible in this learning context (cf. William James case criteria quoted by Bruner, 1987). His thinking highlights the distinct possibilities of this kind of approach as an existence proof of the student learning and project activities that are possible. Many of his peers engaged in similar kinds of relational thinking—although that comparative analysis is left to another time. In order to better understand the influence of the Social Focus framework and the resulting curricular

adaptation, I analyzed Kai's thinking and then related that to the Social Focus framework and pedagogies.

Methods of Data Collection

Teachers were asked to document instruction and collect student artifacts related to instruction during their enactments. I was present at the culminating project presentations and was able to videorecord the presentations of students about their efforts. I have these materials for Kai and for many of his peers—which I selectively share for theoretical reasons. The present analysis focuses exclusively on Kai.

Curricular Intervention Design

Geology education that adopts a reductive, inconsequential, socio-politically neutral, and place-less stance, devoid of place-making geographies and placefulness, falls short of fulfilling its overarching goal: nurturing radical care for geographical eco-relational matters on a planet marked by damage and abuse. In response to this prevailing approach, the collaborative curriculum adaptation of a geology unit, conducted in partnership with second-grade teachers and myself as a university research partner, aimed to instill a sense of *placefulness*. This involves understanding place as "iterative, socially produced, and malleable, allowing for a clearer understanding of the ways that geographies have been used to oppress others" (Germinaro, 2022, p.1).

The focal teacher was engaged in an extended professional learning experience focused on anti-racist and anti-colonial approaches to science instruction following the Social Focus framework approach (see Chapter 2 for details). The particular curricular adaptation that resulted for this focal classroom centered on the unit Social Focus question, *How do Landforms change and how do these changes teach us how to care for Land?* The science unit evolved from being a

reductive and decontextualized unit that focused merely on memorizing types of landforms and the impact of weathering into a geology unit that focused on real-world impacts happening to Land and human agency to be in or out of good relations with Land. Teachers participated in an iterative process of mapping and weaving the unit together aimed at disrupting narratives of nature/culture divide (Bang, et al., 2022) by centering Land-centered literacies (see Figure 1).

Land-centered literacies, such as Aloha‘āina, (Goodyear-Ka‘ōpua, 2013 as cited by Styres, 2018), transcend traditional definitions of literacy that focus primarily on textual interpretations and social interactions related to reading and writing. Aloha‘āina, which means to love and respect the land, is a foundational concept in ancient Hawaiian philosophy. It involves engaging with the environment through observant, interpretive, and expressive skills that connect deeply with natural elements like the wind, rain, animals, trees, and waterways. This form of literacy involves an active participation in the environment, interpreting its signals and ceremonies, and essentially is “about ‘writing themselves into the landscape’ (2013, p. 34).” (Styres, 2018, p. 26). Within the findings section additional information is shared on the pedagogical commitments that were taken up by the focal teacher and other second grade teachers that shifted science learning and instruction focused on Land-centered literacies.



Figure 1: Second Grade Teacher Team mid-way curriculum map of adapted geology unit

Analytical Methods

The primary data source used in this analysis is a videorecording of the focal student, Kai, presenting his final project. I leverage artifacts of his thinking and his peers to provide context for that thinking and to support specific theoretical assertions. Given the complexity of Kai’s thinking, the video recording was segmented into idea units, theoretically interpreted, and then pedagogically analyzed by engaging in the analytical procedures described below.

Segmenting of videorecording into discrete idea units. The videorecording of the presentation was repeatedly viewed and transcribed. Using a standard discourse analysis strategy (Gee, 2011), the transcript was segmented into sets of lines representing a specific topic (or idea unit) related to aspects of relational epistemology (Bang et.al., 2018). This involved engaging in theory-driven *focused coding* of Kai’s thinking based on the Relational Epistemologies Framework (Emerson, Fretz & Shaw, 2011; see also *a priori coding* described by Saldaña,

2015). Through this focus, I identified seven segments that were analyzed and sequentially presented below. The density of Kai's relational thinking was such that these idea unit segments are often quite short (i.e., they represent a specific form of relational epistemology).

Student thinking was theoretically interpreted from a critical, asset-based frame through content analysis. In order to understand the qualities of Kai's thinking expressed in each segment, it was interpreted theoretically for its relational epistemology qualities and connections to the curricular subject matter—as part of the process of developing specific data-based assertions (Erickson, 1986). This was done from a critical theoretical stance. As described by Beach, et al., (2009, p. 129): “Krippendorff (2003) views qualitative content analysis as the close reading of small amounts of texts that are interpreted by the analyst and then contextualized in new narratives; a definition that is a hermeneutic, reader response oriented research stance, and so can be critical as well. What makes a study ‘critical’ is not the methodology but the framework used to think within, through, and beyond the text, such as critical discourse, postcolonialism, women's studies, queer studies, and childhood studies.” By employing the decolonial methodology of *Living in Relation* (Tuhiwai Smith, 2021, p. 192), this analytical process allowed me to understand the intellectual generativity of Kai's everyday thinking related to his project (as opposed to deficits) through a relational lens. This analytical effort to interpret and story is parallel to the relational analysis in Bang and Marin (2015).

Relating student's relational thinking to curricular design framework and pedagogy. In order to study the connection between the student's relational thinking and the underlying curricular framework, arguments were developed around known or plausible connections to the curricular

experience with corresponding insights about the connection to the underlying Social Focus framework and pedagogical model. This allowed for a tracing of Kai's thinking—as an outcome of the design based research study—to the mediating processes and design embodiments that were mostly likely involved in queuing and shaping that thinking (Sandoval, 2014).

Findings

The findings provide a single ethnographic composite narrative of a second grade student presentation captured on video (see Figure 2) that chronologically stories both the pedagogical practices and the learning pathway that unfolded within the classroom. It represents a culminating account of this student's final project and their understanding near the end of the curriculum unit. Across Kai's informal sharing of his project work, we see specific dimensions of a relational epistemology stance being developed and communicated.

As part of a family, friends and school community event that showcased the Social Focus science Landforms unit culminating projects, the presentation is structured as an informal interview between Kai (pseudonym meaning sea and keeper of the keys and Earth), a second grade Land Guardian (Bell & Price, 2023) and myself, identified as a scientist friend of the teacher from the University of Washington. It should also be noted that the presentations were done on pajama day, whereas, Kai is wearing their favorite dinosaur pajamas.

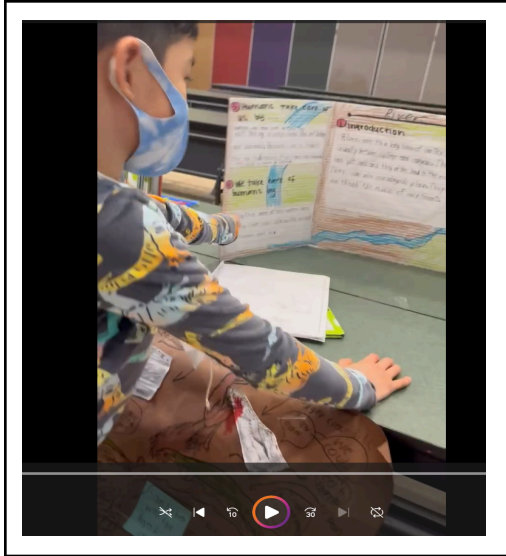


Figure 2: Screenshot of video recording of student's Landform presentation

As a composite narrative, Kai's presentation is largely representative of student outcomes across the class and pedagogical commitments taken up by his teacher and grade-level teacher partners across the district. The structure of the findings sequentially follow the flow of Kai's presentation. Additionally, each section names dimensions of the relational epistemologies framework addressed within the student narrative and pedagogical commitment to provide further insights into how Indigenous science can offer ways to make sense and critical meaning of the world beyond the limitations and harms of westernized science. That is followed by analysis that draws connections between these segments of Kai's thinking and to specific Social Focus Pedagogical Commitments implemented during the unit's instruction. Across these segments of student talk, relational epistemic analysis, and pedagogical connections, I argue that the findings support the argument that the SFPC framework is a promising methodology for infrastructuring curriculum and instruction to promote the eco-relational mattering of consequential Lands, an anti-colonial premise that couples matters of consequential concern guided by the Social Focus framework and relational epistemologies framework (Bang et.al.,

2018). Using this case study as a model, future analyses will explore the relational thinking of Kai's peers and students learning in other classroom enactments of adapted curricular units.

Kai's presentation is segmented into two thematic portions: (1) a series of three framing segments that highlight how Kai was approaching the project, and (2) two critical inquiry segments where Kai is sinking into the details of the investigation. The data analyzed include student and researcher talk across the seven segments.

Segment 1: Introductory Framing of Kai's Social Focus

Student Action and Thinking

After introducing myself as a friend of his teacher and a university researcher excited to learn from second grade geologists Kai shares that he is open to sharing his presentation with me (see Figure 3). Kai begins his presentation with the following introduction:

Kai: "Introduction, rivers are thin long lines of water that are usually between valleys and canyons. They can also split land and often lead to the Ocean, they can also run alongside plains. They run through the middle of rainforests. Some of the spelling doesn't make sense but, that's okay."

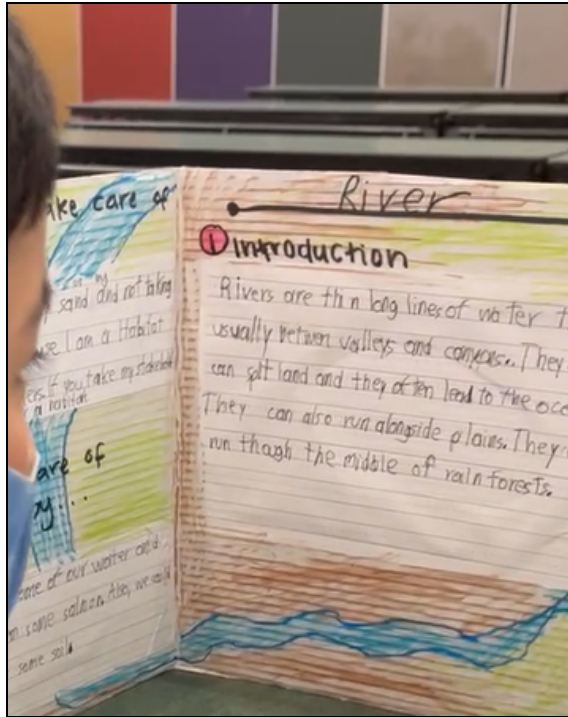


Figure 3: Introduction section of Kai's science River Landforms presentation board

Relational Epistemologies Analysis

Kai's defining of what a River Landform from the very beginning situates the defining of River Landforms in relationship with and geographical context with other Landforms and ecosystems. Within this opening statement the complexity of Rivers shared exceeded the standards which only call for students to name different types of Landforms, as static, abstract parts to a whole diagram. Kai provides his audience a succinct explanation that counters false colonial eco-logics of competition that purposely position Water and Land in opposition, by "expanding notions" of River Landforms as valuable, interdependent actors in the natural world that contribute and have purpose, which align with REF dimensions one (humans with nature) and three (contribution not competition).

Pedagogical Framework Analysis

Kai's opening explanation can be linked directly to the unit Social Focus Question (SFQ) in that it guides students to not only arrive at understanding the prescribed standardized content, but to think and even feel beyond settled answers to consider long-standing realities and relations in future-facing ways. In attunement with REF dimension seven (weigh impacts and responsibilities), students were iteratively positioned to speculate on the SFQ, *how do landforms change and how do these changes teach us how to care for the land?* to "weigh the impacts and responsibilities of knowledge toward action" (Bang et.al., 2018, p. 151). Bound up within the question students were introduced to the standardized content of the unit—what are Landforms and how do they change—alongside this inquiry students were offered a more expansive and consequential inquiry that prioritizes Land, as essential actor and entity with relational, temporal, spatial, physical and justice matters of significance needing care. In an interview, Ammarah shared "on a personal level, I know now not to just take my unit question, for example, and not to just say, this is the phenomenon we're studying. And then from the first three lessons, we've kind of already figured out the thinking. Instead of funneling our thinking into one way, we kind of, we kind of went on to discuss, okay, well, what's happening back home, here and there. What are those communities doing? How are we as geologists also responding to that information?" Ammarah's quote illuminates the transformational shift that opened up for students, as well as herself as a teacher to widen the aperture of learning to see beyond prescribed right answers to see the how, why, with whom and for whom (Philip, Bang & Jackson, 2018). Additionally, she names without naming the tendency for simplicity that occurs within settled science learning regardless if there is a provocative or seemingly cool phenomenon because the thinking has tight enclosures particularly for elementary students given colonial views on children. Rather than use a unit question as a mechanism to direct students along a paved pathway Ammarah and her

teacher partners use the Social Focus Question more like a looking glass for the glass community not only to see pathways of inquiry normally hidden by dominant curriculum, but also to gain a more expansive view to notice consequential stakeholders and matters made invisible, and to critically wonder how science can and should be leveraged to serve Land and students in rightful and radically caring ways. This is evident in Ammarah's statement that "I re-design unit questions, I elevate communities of the global majority, I correct resources given to students by vetting it ahead, does it represent my community in the classroom? I give time and space for debates and discussions rather than rely on written responses, especially because that sets my early literacy learners in failure."

Segment 2: Kai Identifies Humans and More-Than-Humans as Rights and Relations

Holding Stakeholders in Eco-Urban Design

Student Action and Thinking

As Kai continued his presentation we moved to the topic and section of his presentation board on stakeholders. It should be noted that families, peers and friends were given prompts to ask the second graders during their presentations. Since multispecies stakeholders became a central theme of not only the science unit, but also as an anchoring topic that was across content areas such as literacy and art (see Figures 4 and 5), I asked Kai, "So what are stakeholders who are the River Landform stakeholders?"

Kai: "Stakeholders are people, or things, or the people that are impacted by the change.

Humans can be impacted but I did not add that, other stakeholders are crocodiles and anacondas which are a kind of snake, there's another crocodile [points to drawing on poster of stakeholders (see Figure 4) a salmon, salmon, river dolphins and jaguars.

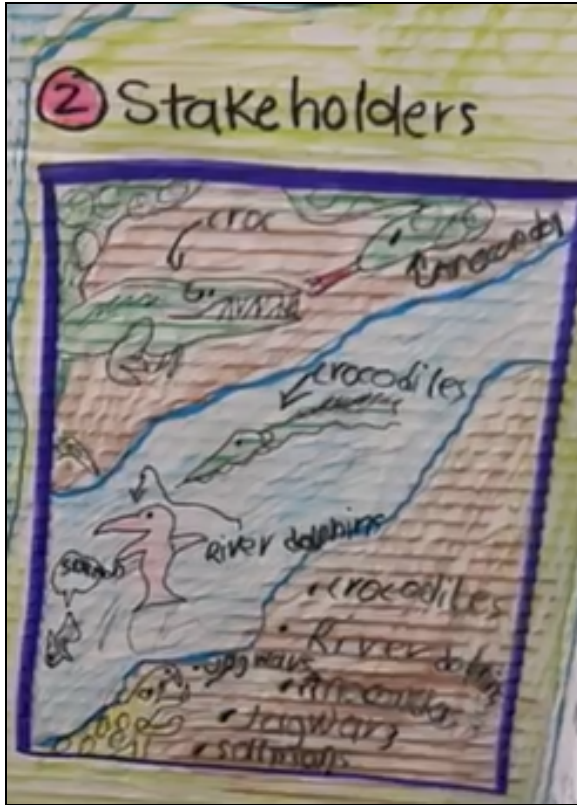


Figure 4: Kai's presentation drawing of River Landform's stakeholders



Figure 5: Kai's non-fiction book on the River Landforms' stakeholder Crocodiles created during his reading and writing class

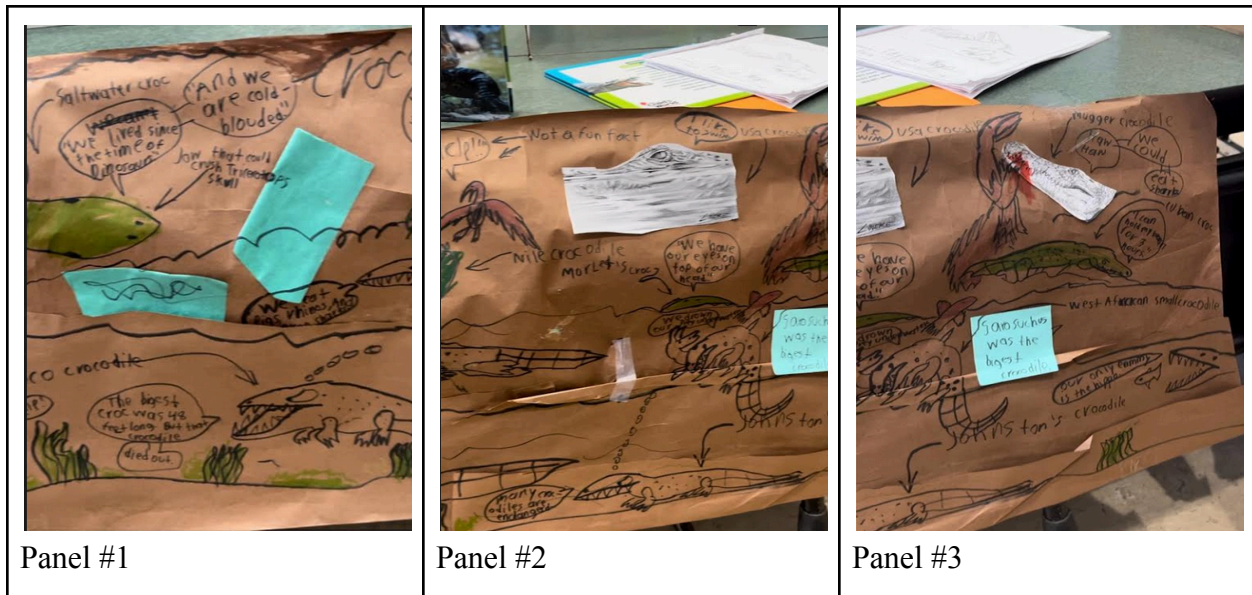


Figure 6: Kai's 3'x 2' art poster about the relationship between River Landforms, Crocodiles and other stakeholders created during art, and reading and writing class.

Relational Epistemologies Analysis

Kai begins his explanation of stakeholders by quickly addressing that humans are stakeholders which attends to REF dimension one (humans as a part of the natural world, rather than apart from it) however he deliberately moves away from human centric stances to identify multispecies stakeholders from various River Landform ecosystems which directly meets REF dimension five (see all life forms as agentic, having person-hood and communicative capacity (as distinct from anthropocentrism)). Additionally, Kai's naming of River Landform stakeholders as crocodiles, anacondas, salmon, river dolphins and jaguars situates these agentic Earthly kin as rights-holding, interest-holding beings deserving of personhood, arguably wellmore than corporations garnering personhood in our legal system. Giving presence to their rights-bearing personhood Kai demonstrates a highly complex understanding of River Landforms by elevating REF dimension six (adopt multiple perspectives, including interspecies perspectives, in thought and action). Although Kai's stakeholder perspective does not name macroscopic level organisms

as mentioned in REF dimension four (focus on whole organisms and systems at the macroscopic level of human perception [also a signature of complex-systems theory) his identification of salmon in relation to jaguars, in relation to anacondas which are in relationship with humans, river dolphins and crocodiles as River stakeholders is exemplar of “ a complex system is defined as the system where there is a bidirectional non-separability between the identities of the parts and the identity of the whole. Thus, not only the identity of the whole is determined by the constituent parts, but also the identity of the parts are determined by the whole due to the nature of their interactions” (Estrada, 2023, p.1). Kai’s complex stakeholder perspective and other complex thinking shared in the findings should not be taken up with a colonial binary lens that links *children with innocence* and *children with nature*, minimizing and simplifying their pre-colonial mind-making understandings (see Chapter 4; Watts, 2013) as endearing and undeveloped (Nxumalo, 2015; Taylor, 2017; Pacini-Ketchabaw, et al., 2014). Instead, Kai and his peers presence multispecies and Earthly forces (see Figure 6) in scientifically kincentric and consequential ways related to REF dimension two (attend to and value the multispecies interdependencies that compose the natural world).

Pedagogical Framework Analysis

Stakeholders as a term, in some ways a contentious term, has most commonly been taken up to mean people with financial and/or political interests in a given endeavor, usually in service to capitalistic conceptions of progress. The intention of using the term stakeholders is to disrupt and counter normative use by weaving the *eco-relational mattering* of those that have been invisibilized or marginalized, in hopes of rooting radical care into curriculum, instruction and the sciences.

Use of the term was purposely done to meet educators within the colonial mindscapes they share as adults in a colonial society that mechanizes and mobilizes white supremacy through collective systems thinking about who holds power to determining how and why science and engineering endeavors happen regardless of the geological disruption across consequential geographies. As a pedagogical commitment, Stakeholder lessons aim to give educators critical pause to unravel their held beliefs to form new, more anti-colonial worldviews. This critical pause disrupts the assiduous pace of the colonial machinery that is the educational system set to over-occupy teachers' minds and lives with the business of teaching to maintain status quo. According to Ammarah, "Pausing to evaluate the intention of the lesson, and from which lens of critical consciousness should I approach this lesson" has shifted her instructional practice, to "center by POC communities as, as communities that are, liberating themselves, showing us examples of what they are doing for the Land." Ammarah went on to share "the stakeholder lessons reached all aspects of our learning especially in reading, in which reading nonfiction topics like biomes or animals, students make intentional connections between habitats and animals' relationships" opening up previously perceived rigid boundaries between subject matter areas. Each of these quotes gives us a glimpse into Ammarah's approach to weaving in Stakeholder lessons not only into the science unit's storyline but as a central theme of learning across content areas. At the onset of the geology unit, following the introduction of the SFQ, students were asked their preliminary thoughts about what it means to be a stakeholder, how they are stakeholders and what they think it would mean to be a stakeholder for Landforms. Importantly, Ammarah's instruction reflected her voiced commitment to nurture students' intellectual health and valuing of anti-colonial perspectives by embracing students ideas about who is a stakeholder to various Landforms, joining, a perhaps at times following students as they

decided the stakeholders they would be researching during their reading class for their science learning. Ammarah's care for students' ontological security, meant trusting them as they journeyed along their own pathways of learning. For Amarah, Kai, other teachers and students the centering of Othered Earthly kin, processes and entities as vital stakeholders entangled in geological matters of eco-relational consequence.

Segment 3: Kai Takes the Consequential Geographies Turn

Student Action and Thinking

Having just named essential River Landform stakeholders Kai goes on to provide contextual examples to support my understanding about how humans should care for various geographical River Landforms.

Kai: "Humans can take care of us by not taking like sand, and not taking our animals because I am a habitat for my stakeholders. If you take away my stakeholders I will no longer be a habitat. Like the Great Barrier Reef, the coral will no longer be a habitat soon because of those starfish things." (see Figure 7)

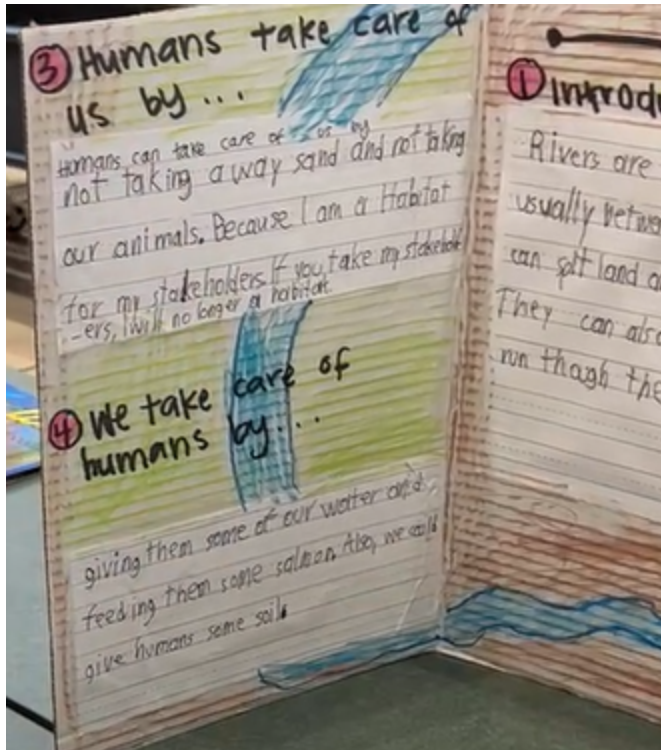


Figure 7: Kai's poster section covering relational care between humans and River Landforms

Relational Epistemologies Analysis

As Kai's presentation progresses, he adeptly underscores the significance of River Landform Stakeholders in addressing consequential geological issues across global geographies to address the SFQ. The excerpt commences with a concise directive stating that humans can care for River Landforms by refraining from extracting sand, which exemplifies that sand is an integral component of River Landforms, analogous to how the muscular system is integral to the human body. Kai's insightful recognition of sand as a fundamental component of River Landforms brings to the fore the critical concern of the schism between geology and geography in formal education. Geology, as traditionally practiced in Western contexts, is predominantly concerned with the exploration of Earth's historical narratives, physical attributes, and the processes governing the configuration of the terrestrial landscape. In contrast, westernized geography encompasses the comprehensive study of the Land, encompassing aspects such as its inhabitants,

soil composition, atmospheric conditions, natural phenomena, and the intricate web of human interactions. This compartmentalization of academic disciplines has a profound impact on students' holistic comprehension of Earth's intricate systems, thereby constraining the manner in which successive generations of learners perceive the Land. It effectively divorces the Land from its broader eco-relational significance, rendering their conceptualization of the Land incomplete. Kai challenges and counters this division by conveying a theoretical stance that aligns with Indigenous Land-centered education scholar Sandra Styres who states that “Land refers to the ways we honor and respect her as a sentient and conscious being. Land, as a theoretical and philosophical concept, comprises storied and journeyed connections of self-in-relationship—to each other, to our places, and to all of creation—as a central model for interpretation and meaning-making” (Bang, et al., 2018, p. 27).

Kai's guidance on how humans should nurture River Landforms aligns with REF dimension one (view humans as a part of the natural world, rather than apart from it) illuminating his socio-ecological awareness of the roles and agency that humans possess, enabling them to either harm or care for Landforms and their stakeholders across diverse geographies, thereby disrupting various geological processes. Further demonstrating his understanding of the eco-relational matters of Landforms Kai expounds on the concept that humans should refrain from disturbing the animals residing within, upon, and around River Landforms, emphasizing that animals, as stakeholders, contribute to the identity of the River Landform as a “habitat.” This understanding recognizes that the removal of sand or the animals that reside within River Landforms would sever them from their intended purpose—REF dimension three (attend to the roles actors play in expanded notions of ecosystems from assumptions of contribution and purpose, rather than assumptions of competition)—and identify

them as agentic entities, characterized by personhood and communicative capacity and distinct from anthropocentrism, which aligns with the fifth dimension of the REF.

In the final portion of this excerpt, Kai extends his narrative across consequential water geographies to draw a connection between River Landforms and Coral Reefs by highlighting the shared concern of losing their identity as habitats. This exemplifies the sixth dimension of the REF (adopting multiple perspectives, including interspecies viewpoints, in thought and action). Although this perspective isn't explicitly macroscopic, it encompasses various natural elements and their interactions, aligning with the fourth dimension of the REF. Throughout this excerpt, Kai fosters the engagement with the seventh dimension of the REF—weighing the impacts and responsibilities of knowledge toward action. He imparts fundamental knowledge about the inseparability and interdependencies between Landforms, habitats, stakeholders, geographies, and geology, imbuing a sense of responsibility to employ this knowledge to inform actions aimed at nurturing Landforms.

Pedagogical Framework Analysis: Attending to Consequential Geographies

Pedagogical approaches, aligned with Kai's viewpoint on Landforms as geological entities encompassing a diverse range of species and the significant geographical and ecological aspects they entail, commenced with a family and community elicitation activity. This activity invited students to identify Landforms of personal importance and narrate the stories associated with these specific geographic locations, thereby anchoring their forthcoming science education within the realm of their cultural, communal, familial, and youth constellar knowledges (Arada, et al., 2023). Contradicting similar efforts to include family and cultural connections to content that simply extract information without a deliberately designed plan to authentically leverage

shared expertise and experiences throughout learning, Ammarah consistently resituated learning in the consequential geographies of her students as well as herself.

The family and community elicitations that students shared became an integral part of the geology unit's learning with purposeful and organic integration throughout the unit in various ways such as using google maps to go on visits to classmates special Landforms as a meaningful Social Focus Touchstone activity to ensure that the geology maintained a "genetic imaginary" rather than default to white geology's" historical regime of material power" (Yusoff, 2018, p.5). Ammarah's commitment to centering students' consequential geographies took the whole classroom on research journeys to learn more about the locations their peers shared. Demonstrative of this commitment, Ammarah shares in an interview how as a class they took the time to "delve deep into taking a look at one of my students home, which was the island of Tonga" which led to Kai's connection to Coral Reef, which then led to his connection to the "starfish things" which although not stated in his presentation referred to the crown-of-thorns starfish which due to warming sea waters has caused an increase in their population impacting the well-being of Coral Reefs, such as the "Great Barrier Reef."

By prioritizing the inclusion of personally consequential geographies Ammarah was also able to presence her own identity in connection to Land and Lands in ways that forged authentic inclusion of students from globally consequential Lands. To better illuminate this Ammarah shared, "We talked about Land, and, as an immigrant, an immigrant parent, an immigrant teacher, I could talk about what Land means to me, and to be here and you know, I have students from Ukraine now, and Russia, and we were able to connect it to that." This place-(re)membering, place-making, and place-belonging that does not shy away from displacement (Yusoff, 2018) by making space for students' consequential geographies opened up

learning pathways that “result from personal or shared concerns, challenges or desires (e.g., concerning a pressing circumstance, threat, or opportunity)” (Bell et al., 2012, p. 273).

“Understanding the stories our students come to us with will help us work with them to build CLL (Critical Land Literacies) while recognizing the complex web of relations that these stories represent and exist within (emotionally, politically, spiritually, and historically)” (Hampton. & DeMartini, 2017, p.263).

It is important to note that while the integration of the Social Focus Pedagogical commitments within the adaptation of the unit greatly contributed to the centering of multispecies stakeholders it was Ammarah’s critical responsiveness and innovation that led to critical stakeholders becoming a method and theme for transdisciplinary learning.

Segment 4: How Transdisciplinary Socially Focused Touchstone Lessons Helped Kai Ideate on the Socio-ecological Context

Student Action and Thinking

As our conversation continues, Kai motions to the next section of his presentation board to share his perspective on the assignment prompt (see Figure 7), *How do River Landforms care for humans?*

Kai: “We take care of humans by giving them some of our water and feeding them some salmon. Also we could give some soil but not ALLLL [emphasis from student] the soil.”

Relational Epistemologies Analysis

This concise yet impactful statement shared by Kai resonates with the scholarly perspective of Tiffany Lathabo King, who posits that the Land seeks a reciprocal relationship with humans. In

King's understanding, “the land's refusal to be separated from flesh” is exuded from Kai’s seemingly onto-eco-relational-intuition that Land is an agentic entity. Significantly, Kai's delivery of this statement was imbued with a sense of firmness, reminiscent of how one would communicate the necessary boundaries for maintaining a healthy relationship with another being. It transcends the first REF dimension, which emphasizes viewing humans as an integral part of the natural world. Kai's message seems to convey the sentiment that, while humans are a part of the River Landform, there are limits to what the Land can provide, akin to saying, "I cannot offer everything of myself."

Kai's effortless transitions and fluidity between the self and the River Landform, which are recurrent throughout his presentation, profoundly animating REF dimension six (adopt multiple perspectives, including interspecies perspectives, in thought and action) to seemingly appear to transcend REF dimension five (see all life forms as agentic, having person-hood and communicative capacity [as distinct from anthropocentrism]). Instead, they suggest a fascinating form of code-switching between nature and human identities, almost resembling a melding of River-hood and Person-hood, to suggest an intriguing Land-human translanguaging. From the first instance of hearing Kai flow between his socio-ecological identities, and the throughout the analysis process, reading, rereading the transcript, watch and rewatching the video, I am always awe-struck by this intuitive practice, humbly recognizing that I been gifted the opportunity to witness Kai’s precolonial mind engaged in moments of *intimate immensities* “an honoring of origins” (White, 2019, p.120)—recognizing “Land is spiritual, emotional, and relational; Land is experiential, (re)membered, and storied; Land is consciousness—Land is sentient” (Styres, 2018, p. 27).

It is noteworthy to acknowledge the comprehensive approach undertaken by Kai in synthesizing insights from diverse activities, particularly drawing from the Social Focus Touchstone Lessons outlined below. This synthesis played a crucial role in shaping his understanding of how River Landforms exhibit a readiness to nurture and care for humans, positing important insights about the intricacies of eco-relational matters of care, as well as REF dimension two (attend to and value the interdependencies that compose the natural world).

Pedagogical Framework Analysis

The term touchstone is defined as a criterion or exemplar, with the plural, touchstones, meaning fundamental part or quintessential feature. As part of the SFPC framework, Touchstone Lessons are intentionally designed as lessons, often varying in length, yet essential to the storyline of the unit, to support students' sensemaking of content to engage in critical meaning-making needed to address the SFQ. These lessons embrace transdisciplinary and relational epistemological methods of instruction and prioritize the critical and liberatory presencing of Black, Brown and Indigenous and more-than-human kin in expansively just ways.

The weaving in of SF Touchstone lessons began with building students' place-based schema and providing geographical context about the removal of a sixty-foot wide levy from a local River landform, opening up “three channels previously blocked from the river and a flood plain spanning nearly 30 acres” resulting “all kinds of animals—birds, beavers, otters and salmon—began returning to the site ‘almost instantly,’ according to Josh Kahan, King County basin steward for the Green River” (Turner, 2022, paragraph 4). This relatively short, yet powerful lesson provided students with an authentic, learning Land-scape, of shared knowledge situated within Landforms, Water, multispecies and humans within a real-world story of

restoration and real-time making of speculative futures, touching on all REF dimensions, except five which was address in subsequent SF Touchstone lessons. For instance, the follow-up Touchstone lesson was a Pixar video called Lava (Kahele, Greig & Murphy, 2015) about a Hawaiian Volcano named Uku, witnessing the love between other species and hoping for and then finding love with another Volcano. This video, endearing and musically engaging gave personhood to the Landform which directly aligns with REF dimension five (see all life forms as agentic, having person-hood and communicative capacity [as distinct from anthropocentrism]).

As the unit progressed with science centered Social Focus and NGSS aligned lessons, Ammarah turned to art to nurture students' eco-relational connections and identities prompting them to make a clay model of themselves as their previously selected focal consequential Landform (see Figure 8, image 2). These clay models remained on students desks creating a classroom space of specialized geologists and geo-identities.

Ammarah's commitment to Critical Liberatory Presencing, a core Social Focus framework principle, returned her to media sources, to provide students with a curated series of videos that centered authentic Indigenous voices and stories. Ammarah, along with her second grade partners, shared with their students the music video of the song *Stand up / Stand N Rock* featuring Taboo (2018) from The Black Eyes Peas hip hop band, along with various other celebrities and tribal members, created in support of the Standing Rock Reservation, and the Sioux Tribe movement as Water Protectors to stop the Dakota Access Pipeline (see Figure 8, image 3). As an emic ethnographic researcher being able to visit the classroom was a privilege and highlight, getting the chance to join during this SF Touchstone activity and the succeeding Lost Worlds (Mam, 2018) lesson filled me with a range of emotions, that included tear-ful joy as they pulled me into the space to sing and dance with them, learning the body motions they

choreographed to the song. This affectively joyful, inspiring and embodied learning nested in eco-relational matters threatening consequential Native Lands served as an invitation to be Land Guardians (see Figure 8, image 4). The efforts to support students learning of Landforms through an eco-relational mattering lens, in ways that positioned humans in relationship and in service to Land included a short video by a Canadian Indigenous group calling people to become Land Guardians. In an interview Ammarah shared how these two videos came to form one of her “favorite” memories “when we watched a video describing the movement of people caring for the Land, Land guardians, students threw their hands in the air and eagerly yelled "we are already part of the movement, they need to know we are here in Washington!" This was a moment that helped me see the sense of belonging to their role and their land as students.”

These video-centered learning experiences resulted in Kai and his classmates making Land Guardian name tags and providing fortifying connective threads to prior and future consequential Lands learning. One of the final SF Touchstone video centered lessons took students on a journey to Cambodia to form connections between local and global eco-relational matters (see Figure 8, image 6). The film *Lost Worlds* documents the ongoing impact caused by corporate and commercial interests in Singapore actively dredging “sand out from beneath Cambodia’s mangrove forests, an ecosystem, a communal way of life” poignantly told from the perspective of a Cambodian woman, in her native Cambodian language, about how her and her peoples’, the Koh Sralau, “relationship to her beloved home are faced with the threat of erasure” (Mam, 2018). In watching this film students were introduced to the fact that to expand the Landmass of Singapore, 80 tons of Sand has been removed from Cambodia since 2007 (Mam, 2018, 02:13). Kai’s excerpt about River Landforms being able to care for humans but not give “all the soil” links back to the deep sensemaking and critical meaning making this film facilitated

for him, and I am sure many of his peers. The film closes with the featured Koh Sralau woman, name not disclosed, posing the question, what worlds are we building and what worlds are we leaving behind?

Through transdisciplinary Social Focus Touchstone lessons and activities of video, art, music, film and relevant books (*You Are Never Alone* by Elin Kelsey [2019] and Soyeon Kim and *The Lost Girl* by Ambelin Kwaymullina [2014]) students were provided learning experiences prioritized matters of justice, cultural significance, relational and collective well-being, futurity and ecological caring (cf. Social Focus framework dimensions of Consequential Concern). Furthermore, the inclusion of various, storied, interconnected, real eco-relational matters across consequential Lands over time provided the geology unit with a heartbeat, pulsing with the thrumming of Land, and the lives of those presenced in rightful ways. These Touchstone lessons, and other Social Focus lessons of (re)membering and critical liberatory presencing geology learning counter white geology's pattern of "the radical ambivalence of the afterlives of geology" and the "Indigenous dispossession of land and sovereignty in the invasion of the Americas" and other geographies "through to the ongoing petropolitics of settler colonialism" (Yussof, 2018, p.4).

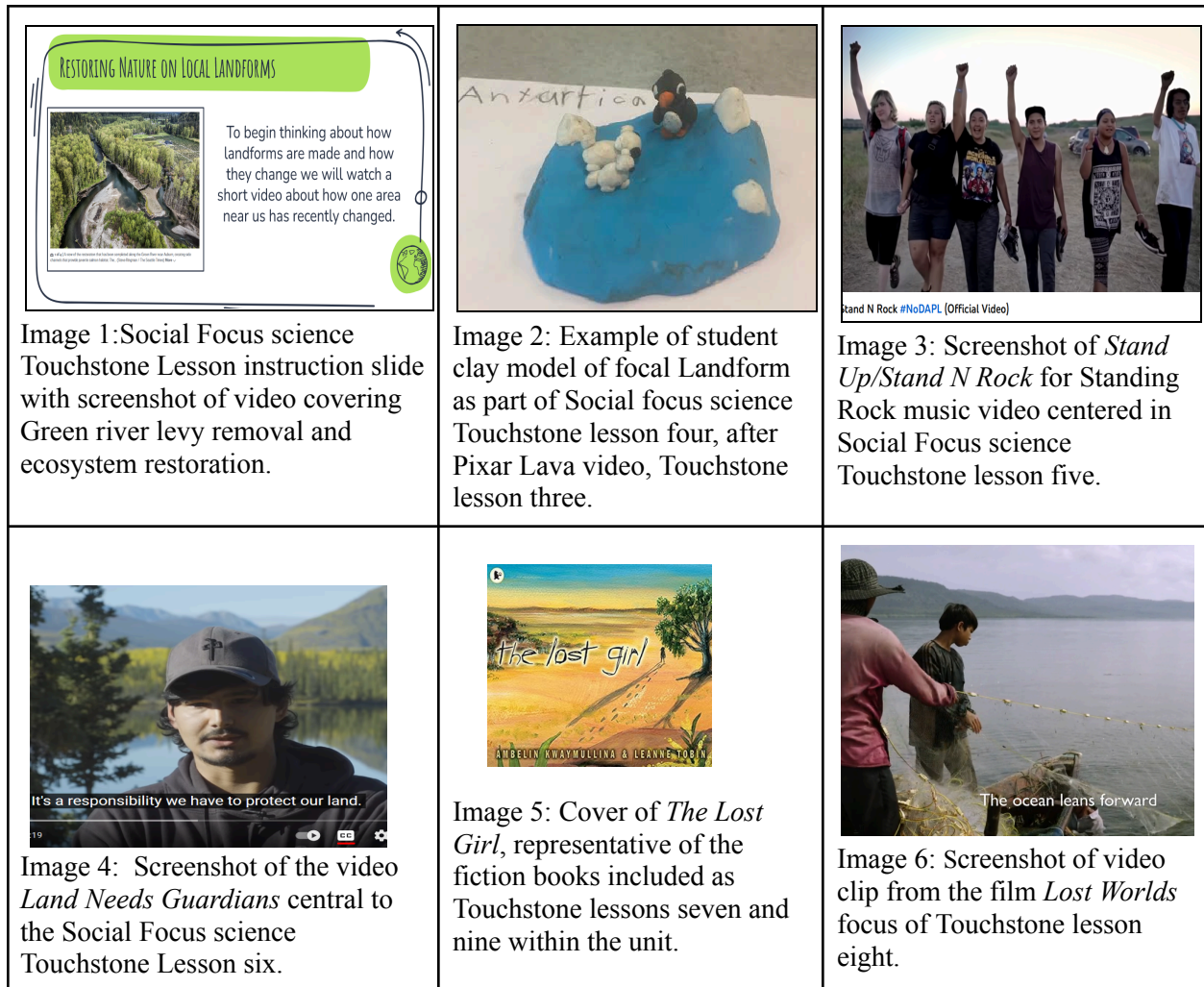


Figure 8: Scope and Sequence of Social Focus Touchstone Lessons and Activities

Segment 5: Kai's Critical Investigation into Levies, Overdevelopment, Weathering and Landforms

Student Action and Thinking

This segment is what I take to be the start of Kai's critical investigation into the context. Please note that it is highly interrelated with—but critically distinct from—the next segment. Kai's following explanation was not on the poster but rather was offered as a vital point of clarification before providing his answer to the prompt and sharing that portion of his presentation board.

In response to the question, “So, how do Landforms change?”

Kai: “Humans and weathering. Weathering is natural impact and the other side is unnatural impact, humans, rivers can change by humans.”

Relational Epistemologies Analysis

"Unnatural impact," encapsulating untold truths, scientific narratives, voices, and geographies intentionally obscured, facilitates deceptive neoliberal narratives of geological universality, eroding the significance of eco-relational interactions on Land. Kai's exploration of "unnatural impact" and his comprehension of ecological dynamics highlight the collective proficiency of young learners in engaging with intricate environmental issues. In challenging the ongoing resistance to teach children about consequential matters, Kai's insight stands as an invitation to critically engage with REF dimension seven (weighing the impacts and responsibilities of knowledge toward action) to bring clarity around REF dimension one (view humans as a part of the natural world, rather than apart from it) whose well-being is bound to the well-being of Landforms .

By holding both—the natural and unnatural ways Landforms are changing and being changed—Kai, along with the majority of his classmates, unfold how they are more than capable of engaging in rigorous sensemaking of consequential geological matters of concern for critical meaning-making about human actions that are fueling climate change and ecological destruction. Kai's ecological consciousness extends to his quote, demonstrating an appreciation for the delicate balance between natural processes and human influence, aligning with REF dimension two—attending to and valuing the interdependencies within the natural world. His nuanced understanding of both natural and human-driven forces shaping ecosystems adds depth to his insights. Children, as evidenced by Kai's engagement, not only exhibit the capability to attend to

and value interdependencies (REF dimension two) but fosters a pluriverse of eco-relational mattering, showcasing the potential for holistic ecological care and understanding in early education. These findings underscore the importance of providing opportunities for young minds, such as Kai, to grapple with real-world complexities and entanglements in and with the Land (REF dimension seven, weigh the impacts and responsibilities of knowledge toward action).

Pedagogical Framework Analysis

In geology lessons focused on erosion, a commonly used experiment involves creating a model of the Earth's surface using soil, which then gradually erodes when water is applied over varying periods or at different flow rates. The primary objective of this experiment is for students to grasp the concept that water causes the erosion of land over time, an already well-established principle.

In this particular instructional unit, teachers were provided with materials by the district to conduct a similar experiment. However, this activity, notably less engaging, employed chalk, water, and a spray bottle. Predictably, although it seemed to be fun to make a mess, the second-grade students found this experiment less challenging, due to the fact that they were already capable of complex hypothesizing. This simplified activity was coupled with a non-fiction book that prompted students to contemplate whether water or land was more powerful, a seemingly innocent purpose, presumably grounded in science, that seeds colonial perceptions of nature, in this case, Water and Land as having antagonistic and aggressive interactions.

As part of a collaborative cohort of educators actively involved in a district-wide professional development initiative centered on fostering anti-racist and anti-colonial perspectives in science education, Ammarah demonstrated a keen awareness of the subtle

tendency within Westernized science to vilify nature while erasing BIPGM people. This often involves portraying nature as the culprit behind catastrophic events, while concurrently rendering humans detached and invisible, thus creating a default of false innocence- white innocence. Such narratives deflect accountability and divert attention from the fundamental role of colonial practices, particularly their voracious appetite for natural and human resource exploitation as the root cause of climate change (Mercer, 2022). This heightened awareness instilled in Ammarah a commitment to represent Water and Land as interconnected and mutually influencing entities affected by climate change. The critical investigations she facilitated intentionally sought to identify natural erosion processes as part of rightful relationship dynamics between Land and Water. Emphasizing the symbiotic nature of this relationship, she highlighted how Wind and Water serve as conduits for nutrient-sharing across various species and components of the ecosystem, while Land imparts shape and structure to contain and direct Water.

Ammarah's implementation of Social Focus critical investigations further countered mainstream approaches to include hands-on activities for the sake of having hands-on activities that are fun to engage second grade students in complex data collection and analysis. In doing so, Ammarah steered her pedagogical focus towards consequential muck-making, disrupting patterns of tidying up curriculum-refusing to get deep in the consequential truths of content through pedagogical lies of omission to maintain the classroom space as a happy place, conveying a robotic message that everything is okay in and outside the empire. This making and remaking of neoliberal education, that thrives in the conditioned pedagogical epistemologies of educators rooted in neoliberal perceptions of morality, favors the “cleaning up” of scientific content complexity through pedagogies and objectives of “fun” distorting life's intricacies into a neutralized, supposedly consensual worldview, moving away “from allowing ambivalence in

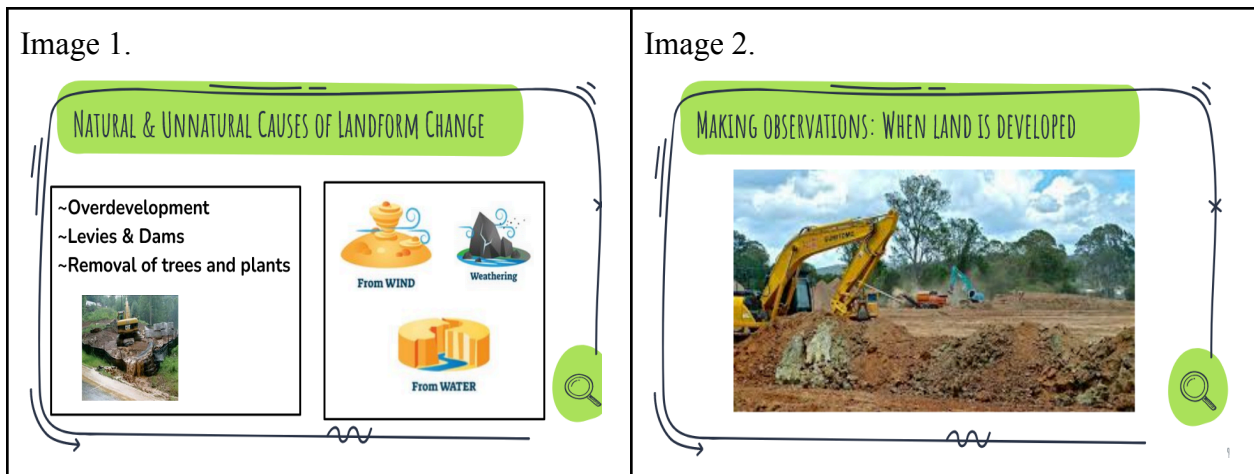
children's emotional lives or supporting ways of being that are more complex than being happy” (Vintimilla, 2014, p. 82).

Ammarah's aspiration to "transform teaching and learning" for her second graders, particularly those identified as "systemically marked ones," with the goal of nurturing them to become “global leaders fostering peace and harmony for all species” (PD exit ticket) goes beyond the constraints of a neoliberal "passive and impoverished conception of happiness" (Vintimilla, 2014, p. 85). Achieving this objective necessitates a heightened awareness, and of how and when the curriculum dissects the significance from the substance of learning, to responsively repositioning learning within the context of situated eco-relational matters of consequence. Ammarah narrates this process as having changed her instruction by way of change her as a teacher,

“ I noticed the different attitudes I have towards my instruction, whether I'm going through slides to introduce a topic or whether I am like, on this side of the room, now I'm running to the other side of the room, now I am listening to a podcast with them. And now I'm introducing an article to them. And so I noticed that I am me, myself, as an educator, I am more engaged and definitely more passionate, because it is something that I know is happening, and something that I know is going to be connected to my students' lives. So to me, if it's meaningful to me, and I show them my passion, they cling to that. And I know that I don't need to drag anybody with me, they are already ahead of me, and they're already wanting even more.”

This process of transformational responsiveness, guided by her students and informed by the Social Focus Consequential Concern principle dimensions, resulted in the implementation of a

series of critical investigations that cast students in the roles of critical researchers and geologists. This sequence commenced with students addressing the question of *why are Edmonds Beach and other Landforms changing*, initiating the inquiry within the local context and establishing connections to various consequential geographies, both globally and personally. The students delved into researching events near the beach, comparing current appearances with early images to discern the impact of commercial development on the area. Subsequently, the class conducted an experiment (refer to Figure 9, image 3) to investigate how commercial development expedites erosion by eliminating native plants—essential, as revealed through graphed data analysis (refer to Figure 9, image 4), for the resilience of Landforms. This process enabled students to broaden their comprehension of how overdevelopment affected the local beach Landform, applying these insights to specific Landforms selected as focal geological formations and geographies for their Speculative Culminating Activity presentations. Ammarah's execution of Social Focus Critical Investigations extended beyond the confines of the mandated curriculum, embedding learning within the intricacies of lived, generationally significant complexities—challenges addressed by Kai and the large majority of his peers, perhaps even surpassing the aptitude of many adults.



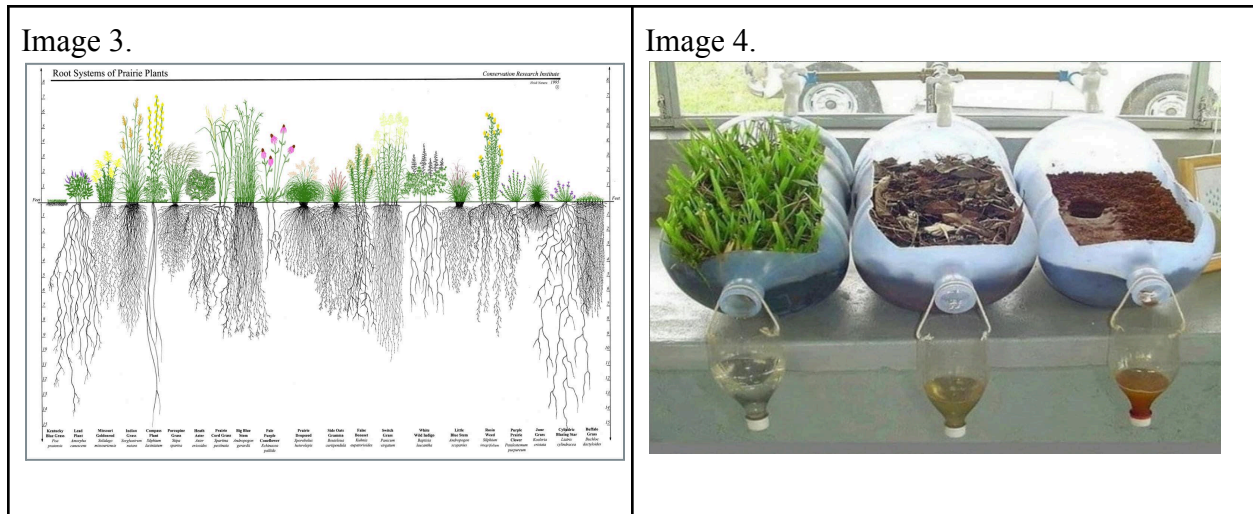


Figure 9: Sequence of Critical Investigations on commercial overdevelopment as an unnatural cause of erosion and Landform changes.

Segment 6: Kai's Critical Investigation Continues into Weathering, River Landforms & Climate Change

Student Action and Thinking

As Kai continues his presentation he provides a storied example of unnatural impact that causes River Landforms change.

Kai: “Rivers can change by humans putting in levies, and levies are little hills that block the water. Levies can change Rivers into ponds, like when a beaver does a dam. Weathering, natural impact, oh umm, other rivers can also flow in and break them apart and then a whole bunch come and come and come until it turns into a giant Lake.”

Relational Epistemologies Analysis

Aligned with the pedagogical storyline Kai's elevation about how the construction of levies is an unnatural impact caused by humans. This is stated matter-of-factly, not as a fatal condition or practice of humans, it is simply stated as an act that is unnatural and disrupts the natural flow of the river. While this matter-of-fact affect may seem just that, given the hyperbolic

concerns of teaching about climate change and the impacts of humans, Kai's approach to the fact indicates that our youth are more than capable of grasping the detrimental impacts of certain human behaviors and leverage that understanding as a new way forward. This distinction of certain human behaviors as being "unnatural impact" is deeply connected to REF dimensions 6 and 7, which focus on evaluating ethical obligations of human action(s) and calls for a responsible approach to action that considers multiple perspectives and long-term impacts on both the environment and all its inhabitants.

In addition to Kai's mentioning of unnatural impact I found intrigued by his explanation of weathering as a cause for Rivers to have an increased water flow. After a more thorough analysis of Ammarah's pedagogical approach, encompassing both sequence and content, I discerned a nuanced depth within Kai's explanation that might be easily overlooked. On the surface, it appears to illustrate how rivers can converge to form a lake. Yet, a deeper layer emerges through critical analysis, particularly in Kai's demonstrative statement, "a whole bunch come and come," which, while not explicitly stated, correlates with the increased frequency of storms due to climate change, leading to heightened flooding and subsequently amplifying the flow of river waters. In this brief statement, Kai subtly addresses both "natural impact" and "unnatural impact," indicative of REF dimension four, emphasizing the macroscopic understanding of whole organisms and systems. Although lacking explicit mention of organisms and scale, Kai's comprehension that rivers converge and experience increased flow with a higher volume of water aligns with REF dimension 2, highlighting the appreciation for and consideration of the interdependencies inherent in the natural world. While this excerpt left me with more questions than answers, it served as a compelling point for investigating Ammarah's pedagogical enactments, which may provide insights into the observed increase in water flow.

The fact that a new, more complex narrative about how River Landforms change that is inclusive of “unnatural impact” caused by certain human behaviors offers insights into ways science education can take up more honest storylines that are woven through with consequential matters with future-facing considerations for attending to climate change and ecological destruction.

Pedagogical Framework Analysis

Building upon the preceding critical investigations, Ammarah consistently offers avenues for making observations, collecting data, and drawing conclusions regarding the impact of anthropogenic climate change on disrupting the natural weather patterns (see Figure 10, to see how lightning and thunder connect to Land) and escalating instances of flooding. Ammarah seamlessly connects students' prior learning experiences related to the removal of plants and trees with the intensified occurrence of storms, guiding them to observe the consequences of deforestation in conjunction with more robust rainfall patterns (see Figure 10).

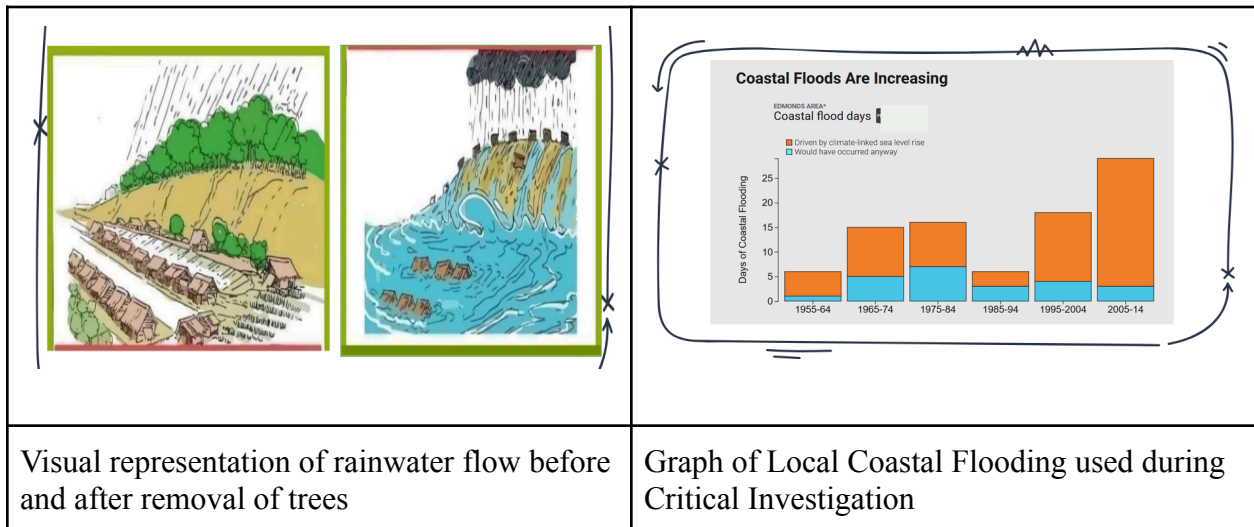


Figure 10: Visual Data sources used in climate change Critical Investigation lessons

Additionally, considering one of the most pressing climate change issue, or perhaps the most known, sea level rise, Ammarah, and her partner teachers engaged students in a hands-on critical

investigation involving the construction a model representing Snow Capped Mountains, Land and Snowpack, to demonstrate one way global warming is contributing to sea level rise (see Figure 11). Although not directly related to the flooding of River Landforms Kai is able to weave together the climate change content provided by Amarrah, along with other content provided such as the removal of the Green River levy, in addition to his own research to form his understanding that River Landforms are susceptible to flooding. Amarrah did not have to include climate change related content into the units, she did not have to provide students with a range of critical investigations that hone in students' attention to the complex eco-relational matters rapidly unfolding and unraveling sacred processes and ways of being due to anthropocentric impacts. However in doing so Ammarah not only disrupts and counters “the anti-intellectualism sustained by existing structures in early childhood education” (Vintimilla, et.al., 2023, p.2) by prioritizing pedagogical commitments that approach “our world with the attention” dissolving the disconnections and distractions that underlie climate inaction” which “also nurtures aa love for the world which is joyous and motivating” (Gillespie, 2019, p. 67).



Figure 11: Critical Investigation exploring the connect between Snow melt, climate change and Landforms

Segment 7: Speculation as active hope for futures of eco-relational mattering

Student Action and Thinking

As Kai's presentation comes to a close he leaves me with a summary of key instructions about how I, and other humans can care for Landforms, as well as an important scholarly citation.

Kai: "You can help by not taking soil and not taking too much salmon, aka overfishing of salmon and also not putting levies in, and again levies are big hills that block water from coming into the Land. I did this all by myself."

Relational Epistemologies Analysis

In his concluding statement, Kai succinctly summarizes key thesis points from his presentation, aiming to offer both "clarity—recognizing the challenges in our world—and imagination, envisioning potential futures beyond situations that may not be inevitable or immutable" (Solnit, 2004, page 22, as cited in Houlden & Veletsianos, 2022, p. 615). In doing so, he strategically identifies speculative points and points of divergence, steering away from current colonial trajectories leading towards catastrophe. For instance, Kai revisits his earlier comment emphasizing how River Landforms care for humans by "feeding them some salmon," reinforcing the idea that River Landforms serve as a crucial "habitat" for salmon stakeholders, thereby assuming the role of their Guardians. Speaking from the perspective of a Salmon Guardian and embodying the identity of a River Landform, Kai advocates for the cessation of "overfishing of salmon" (REF dimension six—adopt multiple perspectives, including interspecies perspectives, in thought and action).

In this concluding excerpt, Kai introduces a speculative blueprint for shaping a future characterized by eco-relational mattering and thriving, challenging the acceptance of a future already in the making (REF dimension seven—weigh the impacts and responsibilities of

knowledge toward action). Kai offers clear and timely instructions for human action, emphasizing the boundaries of River Landforms that humans must respect to foster responsible and reciprocal relationships. As River Landforms, habitat, and Guardians of stakeholders, Kai, despite acknowledging human misbehaviors, maintains a belief in human agency to improve (REF dimension three—attend to the roles actors play in expanded notions of ecosystems from assumptions of contribution and purpose, rather than assumptions of competition, and REF dimension five—see all life forms as agentic, having personhood and communicative capacity, distinct from anthropocentrism).

Kai's insights provide a pathway to better align with REF dimensions, fostering a right relationship with Land and other multispecies stakeholders. This includes viewing humans as an integral part of the natural world, rather than apart from it (REF dimension one), focusing on whole organisms and systems at the macroscopic level of human perception (REF dimension four, also aligned with complex-systems theory), and attending to and valuing the interdependencies that compose the natural world (REF dimension two).

Pedagogical Framework Analysis

Although Amarrah never met the teachers highlighted in the article titled "Youth as Pattern Makers for Racial Justice: How Speculative Design Pedagogy in Science Can Promote Restorative Futures through Radical Care Practices," (Arada, et.al., 2023) she endeavors to extend the transformative practices discussed in the context of middle school to her second-grade classroom. Parallel to the middle school Social Focus speculative culminating activity, which involves students creating vision boards to address the Social Focus Question, "How can and does light serve some communities and not other communities?" Amarrah adopts a transdisciplinary approach for the Landforms unit's speculative culminating activity. This

approach involves aligning SFPC with NGSS content, thereby weaving a curriculum, instruction, and learning pattern that facilitates critical speculation among students regarding the unit's Social Focus Question: how do landforms change and how do these changes teach us how to care for the land? She shares this approach as she discusses the transformation of her science instruction in the following interview quote:

“ I would just take my curriculum and run with it. And now I kind of step back and think, Okay, how can I connect this to another topic? How can I? What is this connected to? What are the issues that are important to the students in my own classroom? And how can I bridge those together so that, you know they're more, of course, there'll be more engagement that happens when seeing what's on the slides, or what what's exactly in front of them as, as a curriculum that matches with what's happening in their real lives. And that's when a lot of powerful discussions come forward.”

Ammarah's dedication to fostering substantive discussions in her classroom motivated her to expand and incorporate science instruction into the non-fiction reading unit. During this integration, she replaced prescribed texts with those chosen by her students, specifically focusing on the Landform stakeholders they had identified. Throughout this transformative process, Ammarah maintained a steadfast commitment to the ethical imperative of emphasizing consequential concerns as central themes. This involved carefully structuring, resourcing, and encouraging students to employ their radical imagination while researching and speculating on the eco-relational matters connecting Landforms, Landform stakeholders, and their roles as aspiring Land Guardians.

Informed by the understanding that, "To be truly visionary, we have to root our imagination in our concrete reality while simultaneously imagining possibilities beyond that

reality" (hooks, 2000, p.110), Ammarah positioned her students as both radically caring and imaginative geologists and co-teachers. This empowered them to share their specialized knowledge within the classroom community as a collective of visionaries. Guided by their individual interests and speculations, students synthesized their research into presentation boards, reports, and murals as part of their Speculative Culminating project (see Figure 12). These projects were presented during a school community event, inviting multi-grade students, families, teachers, and visitors to inquire about the significance of Land Guardianship. Questions such as "Can I be a Land Guardian too? What does it mean to become one?" and queries about Landform Stakeholders and caring for the Landform demonstrated the profound impact of the Speculative Culminating project.

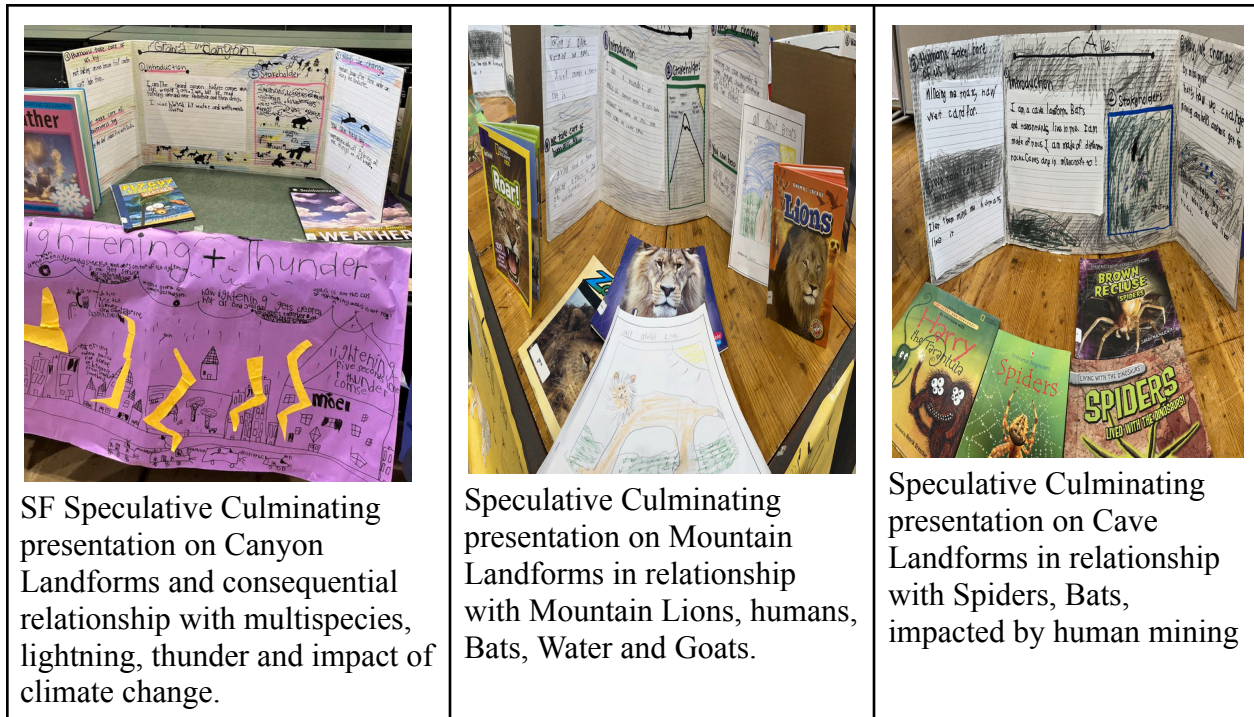


Figure 12: Examples of students' science Social Focus Speculative Culminating Projects

Conclusions & Implications: Creating Spaces for Young People to Imagine Critically Hope-filled Futures for Thriving Lands

There are so many reasons we have been separated. This is what we are re-membering. Our relationship to land is bigger than the trauma that took place on it. Our histories and futures with forest extend beyond the grip of oppression that transpired within them. We are finding our way back to our rightful relationship with the Earth that we belong to. ~Naima Penniman in A Darker Wilderness

How do we, the many, come to forget, to un-know the Land? It begins in our youth, within our learning spaces as disconnected spaces, absent of place; within the science and the geology lessons absent of connected spaces, absent of Place-fullness (Styres, 2018), absent of Land as it is formed; forming—and as it has and can form—memories, pasts, presents and futures. Given the realities facing youth, the tendency for science standards to lead to reductive, abstractedly simplistic geology instruction causes a dis-figuring of authentic and expansive science learning. This dis-figuring, subversively in service to settler eco-logics, severs the very figures, the beings, the Earthly entities, the figured relationships between LandAirWaterStars (see dissertation paper three). It severs the very matter and mattering between, within and because of geological eco-relational systems. Dominant science instruction and curricula make absent the inter-cooperative connections between Land, Air, Water, Stars, and Earthly beings, severing students' sense of belonging with Land and foreclosing the flourishing of their socio-ecological guardian identities (Bell & Price, 2023).

Through a deep reshaping of the curricular landscape, Kai—as an emblematic case study of the expertise of young people—presences himself both as human stakeholder and as the River Landform guardian, positing eco-relational mattering as a powerful outcome when instruction nurtures learning that meets the dimensions of the Relational Epistemologies framework. By situating the dimensions of the Relational Epistemologies framework not as end point but as

(re)new(ed) baseline standards we as science educators, as researchers, as designers of teacher and student learning we can both better stand in solidarity with Indigenous science and as guardians of LandAirWaterStars, multispecies kin and youth futurities.

Prioritizing the dimensions of the REF framework provides a generative outlook on the promising potential of science education. However, as with all theoretical frameworks in education, a pedagogical and methodological approach is needed to guide implementation beyond the epistemic. This map aims to name consequential matters requiring relational care and facilitate the transition towards situated action. The Social Focus Pedagogical Commitments offer direct, yet expansive ways to graft dominant science teaching and curriculum to not only attend to the REF dimensions but ingrain anti-racism and anti-coloniality within learning. Disrupting the inculcation of a settler “culture of uncare” (Gillespie, 2019, p. 89) within science maintains white geology as dead, life-less *stories we live by* (Stibbe, 2015) and die by, calls for an anti-colonial and anti-racist pedagogical grafting of dominant curricula with transdisciplinary stories of consequence and relationality to triage, repair and (re)purposing of science education. Such grafting would necessarily “expand the space for other forms of knowledge, thought-worlds to live” (Tuck & Yang, 2014, p. 817), and for the critical liberatory presencing (Sanchez, 2024; Arada, et.al., 2023) of “what is invisible, noticeably absent so that it can be remembered and missed” (Ahenakew, 2016, p.333).

While the findings in this analysis focus on a specific classroom instance, other actions were at play in other classrooms and at other grade-levels that put into perspective the reality that not all grafting efforts occur, or flourish, in consistent ways. Other analyses will investigate how the Social Focus Pedagogical Commitments get, or do not get, enmeshed within science as a new infrastructured curricular aesthetic and purpose, working at various scales and across various

networks. Additionally, understanding that not all diseased tissue can be healed or saved, nor should it be, equally important research is needed to identify and qualify geoscience and general science education pedagogical and narrative structures, practices and sites in need of cauterization. Genuine anti-racist and anti-colonial knowledge projects would nurture students' sensibilities and "ethics of ecological belonging" (Gillespie, 2019, p.119) across geographies and generations as an anticolonial and antiracist enterprise for a past due educational otherwise centered on the eco-relational mattering and radical care of Earthly kin (Puig de la Bellacasa, 2017).

Additionally the (re)purposing and (re)construction science education needs to seriously (re)connect with interrelated, yet siloed subfields such as geology. All science is situated within spaces and places dynamically and synergistically experiencing micro, macro, chemical, biological, physical and socio-ecological processes and occurrences. Science is situated within science which is written, spoken, drawn, recorded, observed, storied, and felt. It is time to break science free from dominant culture agendas and colonial logics to free up our colonized minds and explore new ways to leverage interrelated science across disciplinary boundaries.

It is essential to also mention that this research holds as anticolonial value that youth are not only whole beings worthy of having their intellectual health cared for but they are also deserving of being positioned not just as learners but also as teachers. Counter to colonial logics and instructional methods that maintain a view of young people as developmentally incomplete, naively innocent, this research, and I argue that education is lagging behind the critical consciousness of youth, who arrive with relevant ethical commitments, perspectives, able to "traverse the cultural ecologies across their lives, grasping onto what speaks to them" to resourcing their "constellar youth knowledges" to engage in consequential sensemaking and

critical meaning-making, as an onto-epistemic right particularly given the precarity of their futurities (Arada, et.al., 2023, p. 85).

It is worth noting that the implications of this research extend beyond the confines of the classroom, offering a call to action for educators, curriculum designers, and policymakers to reconsider and reconfigure science and geology education. The adoption of transdisciplinary SFPC, aligned with the Social Focus principles of anti-coloniality and anti-racism, educators are provided a pathway forward to meet the dimensions of the Relational Epistemologies Framework—and extend well beyond traditional educational standards—by centering Indigenous expertise and the eco-relational mattering of consequential Lands. This not only challenges the dominance of white geology but also contributes to fostering insurgent geology that remembers and re-members the significant beings absent from traditional curricula. This transformation holds promise for reshaping geology education—and science education more generally—to create a more inclusive, interconnected, and responsive educational paradigm that nurtures student socio-ecological identities with a sense of responsibility and relationality toward Landscapes of secured futurities.

References

Ahenakew, C. (2016). Grafting Indigenous ways of knowing onto non-Indigenous ways of being: The (underestimated) challenges of a decolonial imagination. *International review of qualitative research*, 9(3), 323-340.

Arada, K., Sanchez, A., & Bell, P. (2023). Youth as pattern makers for racial justice: How speculative design pedagogy in science can promote restorative futures through radical care practices. *Journal of the Learning Sciences*, 32(1), 76-109.

Bang, M., & Marin, A. (2015). Nature–culture constructs in science learning: Human/non-human agency and intentionality. *Journal of Research in Science Teaching*, 52(4), 530-544. <https://doi.org/10.1002/tea.21204>

Bang, M., Marin, A., & Medin, D. (2018). If Indigenous peoples stand with the sciences, will scientists stand with us?. *Daedalus*, 147(2), 148-159.

Bang, M., Marin, A., Wemigwase, S., Nayak, P., & Nxumalo, F. (2022). Undoing human supremacy and white supremacy to transform relationships: An interview with Megan Bang and Ananda Marin. *Curriculum Inquiry*, 52(2), 150-161.

Beach, R., Enciso, P., Harste, J., Jenkins, C., Raina, S. A., Rogers, R. Short, K. G., Sung, Y. K., Wilson, M. & Yenika-Agbaw, V. (2009). Exploring the “Critical” in Critical Content Analysis of Children’s Literature. *National Reading Conference Yearbook*, 58, 129-143.

Bell, P. & Price, N. (2023, April 20). Restorying Nature-Culture Relations Towards Multispecies Ecological Caring Across Scales of Implementation. Presentation in symposium “Promoting Socio-ecological Caring Practices in Science Education: Models, Possibilities, and Complexities” at the National Association for Research in Science Teaching (NARST) annual conference, Chicago, IL.

Bell, P., Tzou, C., Bricker, L., & Baines, A. D. (2012). Learning in diversities of structures of social practice: Accounting for how, why and where people learn science. *Human Development*, 55(5–6), 269–284. <https://doi.org/10.1159/000345315>

Bruner, J. (1987). *Actual minds, possible worlds*. Cambridge, MA: Harvard University Press.

Cajete, G. (2005). American Indian Epistemologies. *New Directions for Student Services*, 109, 69-78.

Emerson, R. M., Fretz, R. I & Shaw, L. L.. (2011). *Writing ethnographic fieldnotes* (2nd

ed.). The University of Chicago Press.

Erickson, F. (1986). Qualitative methods in research on teaching, In M. Wittrock (Ed.), *Handbook of Research on Teaching*. New York: MacMillan.

Estrada, E. (2023). What is a complex system, after all?. *Foundations of Science*, 1-28.

Gee, J. P. (2011). *How to do discourse analysis: A toolkit*. Routledge.

Germinaro, K. (2022). Healing through geography: A spatial-learning analysis and praxis. *Journal of Critical Thought and Praxis*, 11(3).

Gillespie, S. (2019) *Climate crisis and consciousness: Re-imagining our world and ourselves*. Routledge.

Goodyear-Ka'ōpua, N. (2013). *The seeds we planted: Portraits of a Native Hawaiian charter school*. University of Minnesota Press.

Hampton, R., & DeMartini, A. (2017). We cannot call back colonial stories: Storytelling and critical land literacy. *Canadian Journal of Education/Revue canadienne de l'éducation*, 40(3), 245-271.

Higgings, M & Sanchez, A.,. (in review). Science education for post pandemic worlds: towards a socio-political turn. In Dana L. Zeidler (Ed). *Contemporary Trends and Issues in Science Education*. Springer.

hooks, B. (2000). *Feminism is for everybody: Passionate politics*. Pluto Press.

Houlden, S., & Veletsianos, G. (2023). Impossible dreaming: On speculative education fiction and hopeful learning futures. *Postdigital Science and Education*, 5(3), 605-622.

Kahele, K.T., Greig, N., & Murphy, J.F. (2015, September). Lava. Walt Disney Records, <https://www.youtube.com/watch?v=uh4dTLJ9q9o>

Kayumova, S. & Tippins, D. J. (2021). The quest for sustainable futures: designing transformative learning spaces with multilingual Black, Brown, and Latinx young people through critical response-ability. *Cultural Studies of Science Education*, 16, 821-839.

Kelsey, E. & Kim, S. (2019). *You are never alone*. Owlkids Books Incorporated.

Krippendorff, K. (2003). *Content analysis: An introduction to its methodology*. Sage.

Kulago, H. A. (2019). In the business of futurity: Indigenous teacher education & settler colonialism. *Equity & Excellence in Education*, 52(2-3), 239-254.

Kwaymullina, A. (2014). *the lost girl*. Walker Books Australia.

Liboiron, M. (2021). *Pollution is colonialism*. Duke University Press.

Mam, K. (2018, June). Lost Worlds. *Emergence Magazine*.

<https://emergencemagazine.org/feature/lost-world/>

McKittrick, K. (2021). *Dear science and other stories*. Duke University Press.

Mercer, H. (2022). Colonialism: Why leading climate scientists have finally acknowledged its link with climate change. *The Conversation*.

Newberry, T., & Trujillo, O. V. (2018). Decolonizing education through transdisciplinary approaches to climate change education. In *Indigenous and decolonizing studies in education* (pp. 204-214). Routledge.

Nxumalo, F., Vintimilla, C. D., & Nelson, N. (2018). Pedagogical gatherings in early childhood education: Mapping interferences in emergent curriculum. *Curriculum Inquiry*, 48(4), 433-453.

Orion, N. (2019). The future challenge of Earth science education research. *Disciplinary and Interdisciplinary Science Education Research*, 1, 1-8.

Pacini-Ketchabaw, V., Nxumalo, F., & Rowan, M. C. (2014). Researching neoliberal and neocolonial assemblages in early childhood education. *International Review of Qualitative Research*, 7, 39–57.

Philip, T. M., Bang, M., & Jackson, K. (2018). Articulating the “how,” the “for what,” the “for whom,” and the “with whom” in concert: A call to broaden the benchmarks of our scholarship. *Cognition and Instruction*, 36(2), 83-88.

Pierotti, R., & Wildcat, D. (2000). Traditional ecological knowledge: the third alternative (commentary). *Ecological applications*, 10(5), 1333-1340.

Puig de la Bellacasa., M. (2017). *Matters of care: Speculative ethics in more than human worlds*. Minneapolis: University of Minnesota Press.

Saldaña, J. (2015). *The Coding Manual for Qualitative Researchers* (4th edition). Sage.

Sanchez, A. (2023). Just worlding design principles: childrens’ multispecies and radical care priorities in science and engineering education. *Cultural Studies of Science Education*, 18(4), 1041-1069.

Sanchez, A. (2024). The Social Focus Framework: Anti-racist and Anti-colonial conscientization, consequence and presencing in science education. In S. Tolbert, M. Wallace, M. Higgins, J. Bazzul (Eds.) *Reimagining science education in the anthropocene*: Volume II. Cham: Palgrave Macmillan.

Sandoval, W. (2014). Conjecture mapping: An approach to systematic educational design research. *Journal of the Learning Sciences*, 23(1), 18-36.

Solnit, R. (2004). *Hope in the dark: Untold histories, wild possibilities*. Haymarket Books.

Stibbe, A. (2015). *Ecolinguistics: Language, ecology and the stories we live by*. Routledge.

Stromholt, S., & Bell, P. (2018). Designing for expansive science learning and identification across settings. *Cultural Studies of Science Education*, 13, 1015-1047.

Strong, L., Adams, J. D., Bellino, M. E., Pieroni, P., Stoops, J., & Das, A. (2016). Against neoliberal enclosure: Using a critical transdisciplinary approach in science teaching and learning. *Mind, Culture, and Activity*, 23(3), 225-236.

Styres, S. (2018). Literacies of land: Decolonizing narratives, storying, and literature. In *Indigenous and decolonizing studies in education* (pp. 24-37). Routledge.

Taboo. "Stand Up / Stand N Rock #NoDAPL (Official Video)." YouTube, 4 December 2016, www.youtube.com/watch?v=Onyk7guvHK8.

Taylor, A. (2017). Beyond stewardship: Common world pedagogies for the Anthropocene. *Environmental Education Research*, 1–14. <https://doi.org/10.1080/13504622.2017.1325452>

Tuck, E. (2009). Suspending damage: A letter to communities. *Harvard educational review*, 79(3), 409-428.

Tuck, E., & Yang, K. W. (2014). Unbecoming claims: Pedagogies of refusal in qualitative research. *Qualitative Inquiry*, 20(6), 811-818.

Tuhiwai Smith, L. (2021). *Decolonizing Methodologies: Research and Indigenous Peoples* (3rd edition). Zed Books.

Turner, N. (2022, April). King County tore out a levee near Auburn. Now the salmon are returning. *The Seattle Times*,
<https://www.seattletimes.com/seattle-news/environment/king-county-tore-out-a-levee-near-auburn-now-the-salmon-are-returning/>

Vasconcelos, C., & Orion, N. (2021). Earth science education as a key component of education for sustainability. *Sustainability*, 13(3), 1316.

Vintimilla, C. (2014). Neoliberal fun and happiness in early childhood education. *Journal of Childhood Studies*, 79-87.

Vintimilla, C., Pacini-Ketchabaw, V., & Land, N. (2023). Manifesting living knowledges: A pedagogists' working manifesto. *Journal of Curriculum and Pedagogy*, 20(1), 4-13.

Warren, B., Vossoughi, S., Rosebery, A.S., Bang, M., Taylor, E.V. (2020). Multiple ways of knowing: Re-imagining disciplinary learning. In N.S.Nasir, C.D.Lee, R.Pea, & M.McKinney de Royston (Eds.), *Handbook of the Cultural foundations of learning* (pp.277–294).Routledge.

Watts, V. (2013). Indigenous place-thought and agency amongst humans and non humans (First Woman and Sky Woman go on a European world tour!). *Decolonization: Indigeneity, Education & Society*, 2(1).

White, R. (2019). Reseeding the food system: interview by Emmanuel Vaughan-Lee. *Emergence Magazine*.

Whyte, K. P. (2020). On resilient parasitisms, or why I'm skeptical of Indigenous/settler reconciliation. In *Reconciliation, Transitional and Indigenous Justice* (pp. 155-167). Routledge.

Yusoff, K. (2018). *A billion black Anthropocenes or none*. University of Minnesota Press.

Zeidler, D. L. (2016). STEM education: A deficit framework for the twenty first century? A sociocultural socioscientific response. *Cultural Studies of Science Education*, 11, 11-26.
<https://doi.org/10.1007/s11422-014-9578-z>

CHAPTER 4:
Just Worlding Design Principles: Childrens' Multispecies and Radical Care
Priorities in Science and Engineering Education

Introduction

“Sadly, children’s passion for thinking often ends when they encounter a world that seeks to educate them for conformity and obedience only” (bell hooks, 2013, p. 13).

As a multigenerational collective of Earthly beings and entities, coexisting across spatial temporalities and geographies, we are witnessing and striving to endure the realities and ongoing fallout of global pandemics, climate catastrophe, sociopolitical upheaval and reckonings. Confrontation and conflict between opposing ideologies of settler colonialism and Anti coloniality, white supremacy and Antiracism, challenge the very ways we live with one another, and live upon, with, and from the Earth. Despite claims of neutrality and objectivity, the field of engineering and the education of engineering, quite literally by design, have uniquely contributed to our current convergence of multiple crises and injustice by fortifying and reproducing oppressive power hierarchies and settler eco-logics. The culpability of and urgency for change in engineering education is reflected in Lionel Claris and Donna Riley’s 2012 article, “Situation critical: Critical theory and critical thinking in engineering education.”

“We long ago reached a certain ‘situation critical’ in engineering, in which engineers may have abundant logical thinking skills but no practice of thinking critically about problem framing, power relations within the profession, hegemonic epistemologies of the discipline, or reproductive practices of engineering education. This leaves society with technologies that replicate power relations of the status quo, and the profession

with intractable problems around underrepresentation of white women and women and men of color, and few tools for understanding or talking about these problems, let alone acting effectively for change” (2012, p. 102).

This calling out of a “situation critical” and calling in for change within science and engineering was made a decade ago, and yet, concerns about engineering education and its outcomes have only grown in complexity and criticality. Critiques of the long-standing and current instructional approaches and standards elevate the opportunity to evolve engineering as more than a technocratic endeavor, but as a discipline that can solve global and local problems with consideration of multiple perspectives, social responsibility and dimensions of care (Gunckel & Tolbert, 2018). The application of an ethical stance of radical care within the disciplines of science and engineering requires an eyes-wide-open, caring of neglected things in an aching world (Puig de la Bellacasa, 2011). Such a worthy endeavor would require a transformation of engineering purposes and the education of engineers. While recent and promising critical approaches to engineering education (McGowan & Bell, 2020) and matters of care in science and technology studies (Puig de la Bellacasa, 2011; Puig de la Bellacasa, 2017) provide theoretical grounds for desettling engineering and education research, approaches that foreground and prioritize the radical caring of multispecies and LandAirWaterStars³ have yet to be translated to engineering educational standards and design priorities. By recognizing the lack of care and critical considerations in existing science and engineering education, we can trace these problematic deficiencies to the pervasive

³ I use the term “LandAirWaterStars” to attend to the problematic ways that dominant, Westernized culture collapses Lands, Air, Waterways, Animals, Plants, Stars and Soil into terms such as “nature” or “environment,” in effort to honor each entity and connection. The capitalization is done with intention.

influence of settler colonialism. Settler colonialism suppresses care in science and engineering, stemming from progress narratives fueled and dependent on the consumption of and extraction from LandAirWaterStars, while simultaneously causing the erasure and exploitation of Indigenous, Black, and Brown minds, bodies and lives. By identifying settler eco-logics as they are implicitly and explicitly reified epistemologically and ontologically within science and engineering this study aimed to further efforts to desettle (Bang, 2012) rather than decolonize (Sailiata, 2015), learning spaces for ecological, socio spatial and multispecies justice through approaches of radical care asserted by youth.

Furthermore, despite efforts to increase student voice in STEM classrooms, curricular and pedagogical changes far too often feign the centering of students' epistemic agency, "while actually positioning students as receivers of 'correct' information and practices" (Miller et al., 2018, p. 1056) thereby maintaining hierarchical binaries of adult educator and child learner (Vossoughi, et al., 2021) and status quo affirming epistemologies. This study sought to challenge these realities by mapping youths' ontologies and epistemologies onto science and engineering learning, teaching and doing while engaging educators with youth—not positioning youth as heroes, but as guides, and visionaries that have sight that has yet to be fully impacted by the cataracts of living within the machinery of capitalism and settler colonialism. By examining students' ways of understanding engineering as deeply connected to the care of disenfranchised communities, multispecies and LandAirWaterStars, this study was able to capture students' radical ways of caring in engineering that exceed the parameters of mainstream implementation of science educational and standards, curricular and instructional reform, and moreover provide a trajectory for how to desettle the field of science and engineering education toward just worlding and kincentric flourishing. This design-based research pursues these related research

questions:

1. When situated in learning spaces of desettled engineering education, how do students engage in the co-construction of epistemic agency to promote their ontological security and perspectives on worlding just worlds?

2. What engineering design priorities do students provide the field of engineering education and engineers, for considering Multispecies, LandAirWaterStars, community and global futurities?

3

Theoretical Frameworks:

Attending to and Disrupting Settler Eco-Logics

Leaning on and leveraging Indigenous scholars and scholarship on settler colonialism and settler eco-logics, I seek to call out how westernized science and engineering education secure settler futurities and continue invasion, elimination and mobility through deceiving progress narratives which indoctrinate learners—learners who become scientists, engineers, educators and citizens.

In Rene Dietrich's article, "Made to Move, Made of this Place: *Into America*, Mobility, and the Eco-Logics of Settler Colonialism," he defines settler ego-logics as, "an underlying set of logics through which settler colonial projects produce ecological disruption" through the "regularly unmarked and naturalized logics of exploitation, extraction, and profit maximization operative in settler-nation states" (2016, p. 510). Through acts of invasion, elimination, and mobility, settler eco-logics design, develop and materialize structural trophies and mechanizations of settler industrial progress and capitalist modernity (Tuck &ocollet, 2016). Settler invasion consumes and (re)stories Indigenous ecological expertise and existence through processes of

exploitation and extraction of Native peoples, species, and lands — all of which, through settler eco-logics, are determined to be inevitable, justifiable collateral costs of innovation and progress (Wolfe, 2006). The insatiable appetite of the settler eco-logic of mobility—the “moving in, extracting, and moving on” (Dietrich, 2016, p. 510), along every frontier—devastates and reshapes the Land, forces dispossession and instills narratives of the disposability of multispecies kin and non-settler communities, thereby securing the futurity of settler colonialism and capitalism.

Due to the violent misalignment with laws of nature and care for all beings, the persistence and pervasiveness of settler eco-logics requires the ongoing maintenance of structures and systems of white epistemic and axiological supremacy, which further the elimination and replacement of holistic and Indigenous ways of knowing and being. Within science and engineering, settler eco-logics are more than maintained—they thrive. They thrive within engineering design process models, blueprints, cost analyses, and standards, and are entrenched in the mindscapes of scientists, engineers, and educators. As an opening for disrupting, dismantling and unsettling settler eco-logics, this paper is an invitation to respectfully consider the mapping of our own colonial minds.

On a personal note, I share a story to ground this invitation for future naming and noticing of settler colonialism’s invasion of our psyches and thus our practices, epistemologies and ontologies. During a spring morning, I was sharing a quiet moment outside with my youngest son. As I sipped my cafecito, he softly whispered to me, “Mom, shh, the bunnies are back.” The fact that he knew of the bunnies, and that we even had bunnies, was new to me. After some time of stillness, the bunnies left from our view and I asked my son, “Are you going to name the bunnies?” Without hesitation or emphasis, he simply said, “Mom, what makes you

think they wouldn't already have names?"

Although seemingly brief, for me, this was a moment of deep awareness, awareness that despite actively working to desettle science education, settler colonialism is ingrained within me. I had assumed inferiority of the bunnies, considered them to be absent without my presence, and tried to use naming and labeling as acts of possession and storying into my existence—all linkages towards the colonial logic of human supremacy. I offer this story as a humble exemplar of two points of thought: First, to illustrate my son's knowing located within a pre-colonial mindset (Watts, 2013) and, second, to share my own as a mindset that strives to be unsettled but bears the marks of colonial programming. The intention is also to situate youth within this paper as guides, as intellectuals, but not in the problematic ways that romanticize youth as they connect with, care for and theorize about nature. The aim of this study is to elevate and be in solidarity with scholars such as Affrica Taylor, who challenge the colonial assertion that "there is a paradoxical assumption that children and nature belong together, as sites of innocence and purity, not as always-already entangled and unevenly co-constituted participants in world making" (Nxumalo and Cedillo, 2017, p.101). Recognizing youth as experts in and guides for world-making requires shifting theories of children with/in nature and disrupting adult/child/nature hierarchies in order to recognize the agency of youth, multispecies and LandAirWaterStars as essential to creating connections needed for attending to broken-built worlds (Nxumalo, 2018). Such a paradigm shift starves the roots of on-going coloniality by refusing the ideas that youth are naive, less-than adults, and lacking the power and agency earned by the letting go of childish ways of knowing and caring, replaced by colonial thought and narratives needed to participate in colonial systems of white supremacy. Within the story I shared, as a product of and actor of settler colonialism, my question about naming the bunnies reflects the acquisition and denial of agency of more-than human other, rather than honoring and

recognizing the relational agency myself, my son and the bunny have merely by holding place and consciousness together. My son matter-of-factly knows that his world is inclusive of the worlds made by the bunnies, the bees that visit, the dandelions he says are pretty, the crows that feed on the grubs, these worlds within worlds, all connected, with valid doing, being and happenings, despite/in spite of humancentric enactments and ideologies.

Original Intuition, Emplaced Agency, and Children

If we hold the understanding my son illuminated as truth, then we begin to grapple with the idea that agency is not something given from above, within a hierarchy of power and domination, but rather exists within the matter and mattering of all humans and more-than humans. Vanessa Watts (2013) offers the theory of place-thought, which takes the ontological-epistemological stance that there is a “non-distinctive space where place and thought were never separated because they never could or can be separated” (p. 21). With roots in Anishinaabe and Haudenosaunee cosmologies, place-thought theory is based upon the fact that “land is alive and thinking and that humans and non-humans derive agency through the extensions of these thoughts” (p. 21) and the stance that “if we think of agency as being tied to spirit, and spirit exists in all things, then all things possess agency” (p. 30).

The concept that Plants, Animals, Lands, Air, Waters, and Stars have agency because they simply exist, separate and in relation to one another, not based on what humans determine them to be, is absent in westernized science and engineering. Settler colonial instructions for managing more-than-humans requires erasing their agency, extracting their mattering and experiences in order to subjugate them to the will and agendas of humans and human industrial progress. Settler colonial thought strips away relational complexities in order to reduce knowledge into binaries like nature/culture, good/bad, living/non-living, civilized/wild. This

reductive approach provides a scaffold for domination, for profit, for operationalizing settler eco-logics. As Bang (2017) writes, “Settler-colonialism minimizes the importance of the natural world, and constructs narrow relations between humans and the natural world. Nature’s ontological status is relegated to that of a resource” (p.132). Without relational complexities, knowledge and knowing of self and others are incomplete, inefficient, short-sighted and devastating. Liberatory transformation of science and engineering demands the (un)learning of settler colonialism, which can begin with the understanding that it is a construct that can be undone. It has an origin of place in our minds that informs practice. According to Tiokasin Ghosthorse, returning to our original instructions means a returning to original intuition, which means a returning to our relations and a returning to listening to Earth, knowing she is listening to us, and knowing science is within and because of nature (Young, 2021). “...Original instructions/original intuition is located in what Susan Hill calls the ‘pre-colonial mind’ (Watts, 2013, p. 22). Pre-colonial minds consider what the Land’s intentions might be and how she tries to speak through us and to us. For youth, like my son and the children in this study, who have yet to endure years of settler colonial programming, proximity to original intuition provides clarity of and comfort with relational complexities that holistically presence the agency and beingness of more-than humans. Before we consider the potentialities of centering youths’ logics for radical care approaches in science and engineering for worlding common worlds (Latour, 2004), we need to give attention to how children are not being perceived and/or positioned in this study.

Stances on child development in this study are contrary to settler tropes of young children being developmentally inclined to have a kinship with multispecies, LandAirWaterStars entities and natural forces as evidence of naivete—as a beginning stage of human development, not yet complete. This research challenges the perception that humans become more whole as they move away from so-called innocence, along developmental trajectory towards adulthood,

adulthood measured by achieving a nature/culture divide which further validates anthropocentric dominant ideologies and ecological harm. (Nxumalo, 2015; Nxumalo, 2016) Instead, this study aims to trouble such perceptions of childrens' development by elevating that this departure is anything but natural. Rather, it telegraphs the onset of settler colonial programming; it is a narration of severance from eco-social relationalities; it is cyborg-making (Haraway, 1991). Centering relational pedagogies and relational onto-epistemologies of children means understanding that they are holistically, geographically, biologically, culturally and generationally situated in multispecies entanglements, as actors and witnesses of the worlding of their always-becoming worlds. (Taylor and Pacini-Ketchabaw, 2018) This study aimed to design pedagogical conditions and engagements to disrupt the inscription of settler eco-logics by supporting the ontological security of students' complex, original intuitions and relational ways of knowing, considering and caring for all species and LandAirWaterStars. (Bang & Marin, 2015) Caring for students' ontological security requires seeing that youth are whole beings, capable of navigating complex realities and futurities and deserving of having their heterogeneity valued and presenced. To do so, particularly in formal learning spaces, means to design pedagogical practices and learning that disrupt settler colonialism conditioning through moments of critical speculation that support "students in navigating through time-space relations by creating temporal and spatial synchronicity that refused settler colonial erasure" (Bang & Marin, 2015, p. 542). Countering colonial hierarchies of being and becoming requires the (re)opening of paradigms and pedagogies that not only embrace but also honor youths' pre-colonial stances on and relationality with nature—providing adult educators and engineers with radically caring insights and sight.

Radical caring, absent from idealistic, neoliberal notions and damage-centered savior agendas, but rather is informed by critical pedagogies, provides a legitimate and

liberating opportunity for the social dreaming (Espinoza, 2008) of a hopeful otherwise beyond the dominant and domination of beings and worlds. As Hobart and Kneese (2020) write:

“Radical care can present an otherwise, even if it cannot completely disengage from structural inequalities and normative assumptions regarding social reproduction, gender, race, class, sexuality, and citizenship (p.3) “...care is about the survival of marginal communities because it is intimately connected to modern radical politics and activism....During moments of crisis, radical care allows communities to live through hardship” (p. 10).

Aims of evolving science and engineering to have a pulse, a heartbeat (Frausto et. al, 2022) necessitates pedagogical (re)designing and (re)purposing to center youth knowledges and radical care while supporting youth as they learn about and speculate about the world and the world that is yet to be.

Methods

Curricular Design Implementation

Engaging students in critical speculation at the boundaries of settled, Anglo-western, science provides escape routes, pathways and expansive learning landscapes. It presences ontological intuitions, epistemic awarenesses and socioecological complexities so youth agentially engage in worlding practices for social change. In consideration of the urgent need to desettle science and engineering that reifies settler colonial eco-logics this study leveraged the Critical Speculative Design Pedagogy framework (Arada et.al., 2023) to move teaching and learning

outside the enclosures of normative engineering pedagogies and processes.

Critical Speculative Design Pedagogy Framework (CSDP) aims to attend to the call for socio-political, socio-ecologically conscious teaching and learning that focalizes and vocalizes *the how*, *the for what*, *the for whom*, and *the with whom* of teaching and learning (Phillip, Bang and Jackson, 2018) and be mindful of how understandings of the past and present inform the designing and building of worlds in which youth are critically enmeshed. Thus, the CSDP framework is grounded in the recognition that youth have the epistemic right to engage in learning that honors and centers their ontological orientations, knowledges and ways of knowing within consequential, future-facing endeavors. Within CSDP, youth are valued as generational stakeholders who can and necessarily are positioned to speculate about a best ways forward to design for just worlds, despite and in spite of unjust complexities and socioecological doings and undoings. CSDP framework includes instructional design elements of *constellar youth knowledges*, *consequential concern*, *critical liberatory presencing*, *futurity play* and *kindred relationality*. These design elements are not to be understood as separate but as interwoven, as they form the connective heart tissue of radical care desperately needed in an engineering and engineering education centered on social and multispecies justice (Arada, Sanchez & Bell, 2023).

Implementation of the CSDP framework in the curricular design of this study foregrounded students' constellar knowledges, not merely as moves towards inclusion for assimilative participation, but for visibilizing the onto-epistemic heterogeneity missing in reductive, zero-sum learning (Warren et al., 2020). Designing curricular learning that priorities the presence and weaving students' generational and intuitional constellar knowledges disrupts epistemic arrogance and hierarchy espoused in dominate science and engineering education. This foregrounding carves out pedagogical possibilities for epistemic desettling that produce

expansive learning Landscapes for community and global mattering(s) that are beautiful, troubling and yet to be dreamt. Within engineering education, the CSDP framework approach illuminates the ways engineering design and content are situated in real-world contexts with consequential generational and socioecological concerns. By grounding engineering learning in consequential concerns, students' critical sociotechnical literacy is nurtured as they "think about the social implications of their designs and their impact on the social structures and sustainability of communities" (McGowan & Bell, 2020, p. 15). The CSDP framework pushes on ambiguous undertakings and understandings of "sustainability" and encourages communities to leverage a critical liberatory presencing (Sanchez, in press) which calls for the dignity-affirming and generative representation of Black, Brown and Indigenous brilliance, experiences and futurisms (Espinoza & Vossoughi, 2014). This necessitates shifting engineering, and engineering education, away from technocratic problem-solving and product-development agendas, towards engineering that prioritizes boundless speculative thought and consideration of and for kincentric flourishing (of community, multispecies, and LandAirWaterStars). These expansive priorities, as they are taken up in CSDP, negate moves towards eco-apocalyptic, universalist stances that by default secure only white futurites. Rather, these priorities aim to engage in the cultivation of what Mitchell and Chaudhury (2020) call *plural imaginaries*, that "exceed white visions of 'the' end of 'the world', embodying much wider, diverse, and transformative concepts of, and beyond, 'humanity', 'nature', and 'the planet'" (p. 2). Engineering education that positions learners as co designers with shared responsibility to (re)design just worlds of reciprocity and relationality necessarily requires critical speculation beyond the confines of settler colonial and neoliberal logics of progress and technocratic innovation.

Learning Context

This study is part of a longitudinal, multi-scale research practice partnership (RPP) between the University of Washington and a local school district. In effort to attend to a leading edge of science and engineering education research, a cohort of teachers participated in a kindergarten through-sixth grade pilot of the Social Focus Initiative. Guided by the Social Focus framework (Sanchez, in press), the Social Focus Initiative began in local middle schools, aimed to support the teacher learning and development of justice-oriented, culturally resurgent science instruction. For this study, two white teachers from different schools opted to pilot a Social Focus third grade science and engineering unit in collaboration with myself and my graduate researcher partner, Kelsie Fowler. The partnership employed a social design research approach, which positions teachers and researchers as collaborators in the pursuit of transforming science and engineering education. Between the two teachers, there were three classes totaling 64 students, with one of the teachers having two science classes. The two schools shared similar student demographics, and in aggregate across both schools, 55% of students identified as being part of racial and/or cultural groups representing people of the global majority, with the remaining 45% of students identifying as white.

It is important to note that the research conducted in this study was done during the height of the COVID-19 global pandemic, which abruptly moved public school learning from the classroom into the homes of teachers and students. Given these unprecedented conditions, teachers, students, and families traversed along a steep learning curve of digital remote instruction. Necessarily, teachers and researchers adapted to these new conditions, editing lessons for compatibility with online learning platforms. Therefore, data collection for this study was done remotely. Due to mandates enforced by the district, science instruction time was reduced, impacting the scale of the research and partnership. Importantly, these unforeseen

complexities and constraints are not shared to paint a scenario of limitation, but rather to highlight that the children in this study embraced the expansiveness of the new curriculum despite such conditions, brilliantly offering up kincentric engineering design principles to move the field of engineering toward just worlding.

Curriculum Enactment and Data Collection

Selection of the third-grade physics and engineering unit was based on previous analysis of students' conceptual models and observational data from multiple classrooms, which revealed that students' curiosities and speculative questions exceeded the bounds of the adopted curriculum. This district adopted curriculum unit leveraged the phenomenon and investigation of maglev trains, which is seemingly contemporary and provocative. However, the curriculum reflected zero-point epistemological learning and storylines with ridged enclosures, which steer students toward content standards which, in this case, were myopically focused on forces of magnetism and gravity. Early analysis of students' conceptual models and classroom discourse showed that students attempted to speculate about how and where these trains existed, or if they existed at all, and if so, how they were developed, how they function beyond rising and falling, and if they are safe. Despite students' desires to learn about the sociotechnical complexities of maglev trains, the reductive curriculum and district constraints failed to attend to students' inquiries, as they were not related to the standards needed to learn to pass the end of unit assessment.

Based on this evidence, my research partner and I co-created pilot lessons using the CSDP framework to contextualize high-speed train development in real global socio-ecological spatial geographies while also providing consequential learning opportunities to nurture students' intellectual health. To support youth intellectual health, we engaged them in the “intellectual

work of storying” and “dreaming forward” about “healthful ways to think about the world and to deliberate about the world, to think about what could be, to think about the challenges of living in Westernized systems things like decolonization, things like understanding colonial systems but also things like how do we generate a new always” (Bang, 2020, 20:14-20:36). Developing pilot science and engineering lessons to nurture students’ intellectual health required shared understanding among the design team that youth are already positioned within power-laden socio-ecological entanglements that are ever-present in sociotechnical developments. Therefore, youth were provided opportunities to critically speculate and get into the muck that is at the intersection of technoscientific development with cultural, multispecies and ecological realities and futures.

The unit created for this study aimed to engage third grade children in speculation and deliberation about science and engineering innovation, centering learning around the Social Focus question *What and who should scientists and engineers consider when developing technology and solutions?* The arc of learning began with a family and community elicitation about the role and experiences with transportation and speculative designs of possible future forms of high-speed transportation. This type of elicitation moves away from performative and interloper lessons that ask students’ families to share how the content resonates with their lives, never to be revisited. Instead, the elicitation was designed as a self-documenting activity to presence the expertise within students’ worlds and communities, to inform how content is considered and move learning outside the barriers of settled learning (Tzou & Bell, 2010). Following the elicitation, perspective-taking lessons and materials were created to continue to move content and learning to challenging positivistic, technocratic engineering stances to shift learning towards learners’ kincentric orientations and intuitions.

Grounded in posthumanist feminist science theory, perspective-taking learning activities, called *stakeholder lessons*, push for the critical liberatory presencing of the oppressed and invisible human and more-than-human actors (Medin & Bang, 2014). The pedagogical practice of perspective-taking positions learners to traverse spatial and temporal boundaries and engage relational epistemologies to connect content to complex roles within socio-ecological systems and places (Pugh et.al., 2019). For this study, perspective-taking began within student-led discussions, which asked them to consider who is an engineer and where engineering is done, moving perspectives away from white identities and countries as dominant doers of engineering. Students then learned that high-speed trains are a global endeavor by conducting critical research activities on four real-world high-speed trains currently in stages of development or proposed for development. Discourse prompts and activities were embedded to help students deliberate as peers about why the trains were being proposed or developed, consequential concerns about development, and who and what should be considered when making final decisions about the trains.

These critical research perspective-taking activities were created to help students consider the complexities of building the train, including the impacts to local communities and impacts to natural environments. The unit culminated with students taking the perspective of engineering design team members tasked to invite the stakeholders they considered to be essential to determine how and if the train would be built. (See Appendix B for detail.)

Qualitative Analytical Methods

To address the proposed research questions, I employed a thematic analysis approach (Braun & Clark, 2017). Thankfully, I was able to attend the majority of all the science classes in this study as an insider participant, therefore I took ethnographic notes while reviewing the class

recordings, documenting the interactions between students and teachers and peer discourse in the whole group space, break-out rooms and within the online chat space. This approach and process was emulated by my co-researcher Kelsie Fowler, which informed our conversations, guided by a grounded theory approach that asks, “What is happening here?” (Charmaz 2001, p. 337).

Through the analysis of notes, classroom video and student artifacts, with critical attention to how students engaged in the threading and weaving of science and engineering content and their constellar knowledges and perspectives on multispecies and LandAirWaterStars, patterns of socio-ecological care in engineering became evident. These patterns materialized succinctly in students’ culminating assignment of Stakeholder Design Meeting Invitations, making these artifacts the primary data set and unit of analysis for this study. I transcribed each of the digital Stakeholder Design Meeting Invitations (n=60), then used a thematic analysis method (Denzin, 2005) to identify salient themes within students’ responses regarding who/what they were inviting to the train design meeting. Initially using an open-coding approach (Strauss & Corbin, 1998) of students’ invitations, I created categories of stakeholders, such as farmers, plants, animals, and grouped stakeholders. Then through a process of focused coding (Miles et.al., 2014), these categories were organized to identify core themes in the invitations, asking the questions, *how are students positioning essential stakeholders in the design meeting* and *what do they elevate as vital considerations when designing and developing the maglev train?*

Findings

“Are there any more human beings, seems to be there are a lot of technical humans.” — Tiokasin Ghosthorse

Promising and prescient events of anticolonial engineering education and the field of engineering are presented in the following findings. The findings are structured chronologically, narrating how the virtual classroom transformed into a space of epistemic sovereignty for students, creating contestations of coloniality and presencing kincentric flourishing within engineering. The findings begin with how classroom learning shifted away from settled learning by asking youth to center their inter-intrapersonal connections to transportation and the engineering of future transportation. The storying of the findings then moves forward through the learning experience, sharing the ways students increasingly engaged in contestations of colonial, technocratic engineering as they learned more about the global socio-ecological context of the trains. The findings conclude with students’ four critical and radically caring socio-ecological engineering design principles, which surfaced from analysis of their culminating activity.

Desettling through Student Inter-Intrapersonal Elicitations

In alignment with the CSDP framework and in effort to break through the walls of reductive science and engineering learning, an elicitation lesson was created for teachers to provide an opportunity to begin learning with the centering of students’ authentic and expansive inter intrapersonal connections to transportation and designing transportation. For this elicitation activity, students asked a family or community member(s) about what they thought about local transportation, what works, what doesn’t work, to share stories about their experiences or

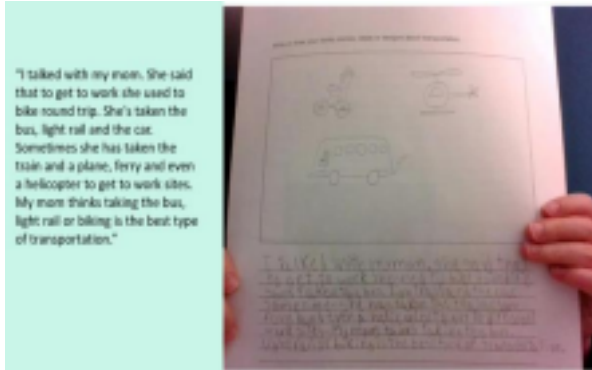
knowledge about various forms of transportation and to speculate about what the perfect transportation system would look like in the future. (See Figure 1: Student elicitation examples.)

Community and family responses predominately focused on utility, uses and designs of transportation, but at the same time hinged on the belief that their transportation system, as it is, is limited in its usefulness because it lacks consideration of community, the environment, and future socio-ecological needs. For example, a student's father who was video interviewed shared that there are many challenges to consider when designing local public transportation. He stated, "This is needed so bad," and at one point he says, "and here they have a lot of water to deal with and that is hard. They are building bridges because they can't just build right on or in the water....yeah, this is something they need to think about." What goes unsaid here is *why* water must be considered. However, he seeds Water, and Water-placemaking as a key stakeholder and consideration in transportation design for the future.

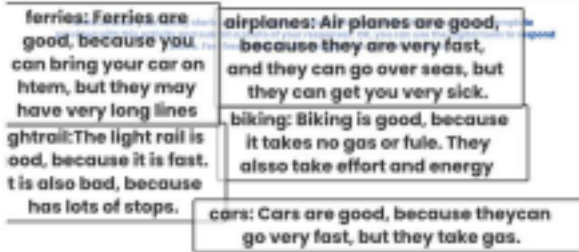
The elicitation activity countered dominant positivistic views of engineering and transportation that are pushed when learning is absent of personal and real-world complexities. By opening up learning to invite inter-intrapersonal connections, students and their families were elevated as valued sources of knowledge. Beginning with the inclusion of personal, complex views about the unit topic expanded learning and initiated the unit as an investment in youth's intellectual health, opening the classroom as a space to grapple with the consequential entanglements of engineering and living, lived worlds.

Figure 1: Student transportation elicitation examples

1.) This student example shares a discussion they had with their mom about her experiences with transportation.



2.) This student decided to grapple with the complexities of transportation based on their own collective understandings.



3.) "This student and their brother dreamed up a transportation device that moved people from an urban downtown immediately into a forest."



In class discussions about the elicitation lesson, students' inclination to *stay with the trouble* (Haraway, 2016) was evident. Students weighed complexities when several students elevated the fact that not all families have access to affordable transportation, such as one student sharing that light rail "routes are probably great for families that want to go to a big soccer game but may not be close to other areas where some families need to go, to like work or see family." Class discussions toggled between the tension of naming human-centric "benefits" of

transportation made by teachers such as being “fast,” “efficient” and able to “go far,” juxtaposed with students’ holding of socio-ecological concerns, such as saying that the trains would cause “too much pollution,” “we need solar panels that could be used by different forms of transportation,” “for some people it might not be a good thing,” “maybe there are longer lines for some people” or that the trains will be “too expensive.” The elicitation and initial discourse activities illustrate youths’ keen sensibilities to not just take content at face value by challenging canonical stances of technological progress. They also speak to the students’ abilities, capacity and interest in taking up consequential concerns, different perspectives, and exploring the tensions and possibilities between those perspectives.

Student onto-epistemic resistance and refusals for the centering of kindred relationality

As the learning progressed, students were asked to consider research on four real-world high speed trains being proposed for development or in stages of development in Asia. During this activity, students' inquiry into socio-geospatial realities increased, surfacing more consequential tensions about the true costs and untold truths about the trains. For example, during whole-class discussion about the pros and cons of high-speed trains, when it was mentioned that residents near the train would be able to commute to work, several students added counter points to residents’ proximity to the train as a potential cause of “noise pollution” and “litter” and inquired if the tracks would actually cause more fatalities and property damage. In one student breakout room conversation about whether or not a particular train should be built, the following was said:

Student 1: “I don't know what to think because it is a lot of money and doesn't go that much faster. [long pause] What do you think?”

Student 2: “I--I don't really know what I think because yeah it can break trees and kill

animals and stuff to put it in and---and how you said Elijah, it costs 88 million dollars!!!! Like wow! But I do like that they aren't broke by earthquakes, so they won't need to be fixed and all that. Just put in. But yeah, I don't really know."

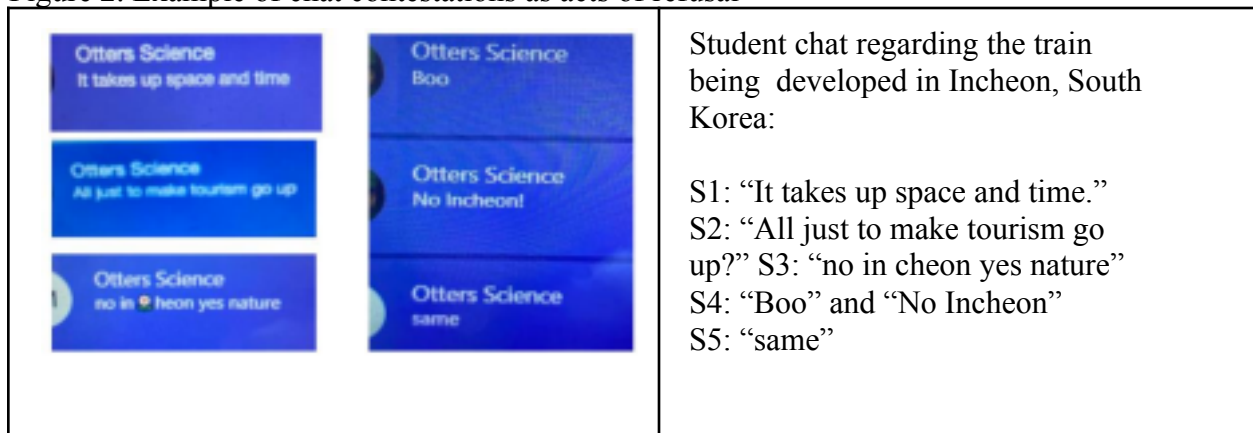
The above student conversation excerpt is representative of how the third-grade students in this study embraced the troubling of the development of the four trains they researched. Designing science and engineering education that prioritizes consistent, expansive, critical and speculative learning opportunities (re)opens up the classroom as a space that contradicts learning that attempts to espouse "one right answer" white supremacy traits (Jones and Okun, 2001), which fails to nurture students' intellectual health.

The next lesson in the sequence of critical research learning shifted from having students investigate four trains to focusing specifically on one high-speed train being proposed for development in South Korea. Although *either/or thinking* is a trait of dominant white supremacy culture (Jones and Okun, 2001), binary instruction and instructional practices, such as pro/cons lists, continued to be employed by teachers. However, students resisted this simplistic mindset, opting for more rigorous thinking and questioning if there could truly be pros with so much harm to nature and communities. Students were attuned to settler colonial default thinking, which considers increased tourism and economic growth as uncomplicated pros and collapses cons into "impacts to nature," invisibilizing LandAirWaterStars, multispecies animals and plants and oppressed human community members.

The more teachers tried to "see both sides" (teacher quote during a post-observation conversation), the more students engaged in acts of contestation and critical inquiry, which ignited a culture of collective refusal and reclamation of the learning space. Evidence of this shift arose in the way students began to take ownership of the online chat space to presence

their onto epistemic refusals. Knowing that the teacher did not often monitor the online chat space, students engaged in rogue side conversations pushing back on narratives about the train being a technological innovation engineers had created for human progress. In several instances, students even resisted releasing the chat space after class ended by continuing peer discussions after class in a way that refuted the in-class conversation. (see Figure 2).

Figure 2. Example of chat contestations as acts of refusal

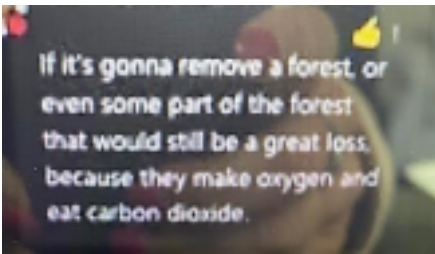
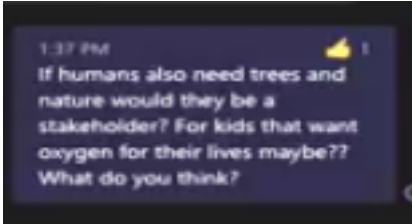
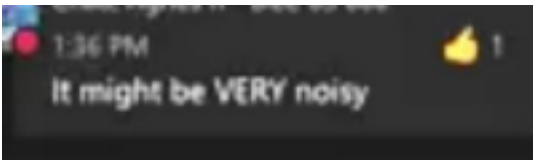
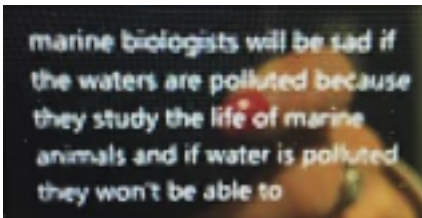


Following the lessons that engaged students in learning and wrestling with background research on the focal train, students engaged in a set of stakeholder lessons. The design of stakeholder lessons call for the critical liberatory presencing (Sanchez, in press) of beings and natural entities that all would otherwise be marginalized in normative science and engineering education. The stakeholder lessons also intended to promote perspective-taking to answer the unit Social Focus question, *What and who should scientists and engineers consider when developing technology and solutions?* While stakeholder lessons were intended to surface this question, the students were already far ahead of the designed curriculum, considering perspectives and beings absent from the conversation from the very beginning.

As learning unfolded, students' resistance and refusals and moves to (re)story the

engineering storyline further flourished when classes began identifying stakeholders. The lesson began with teachers attempting to scaffold the class discussion to create another binary list: stakeholders that would benefit from a train and those that would not. Students pushed back on the ‘either/or thinking’ list making by repositioning and reiterating relational epistemologies (Cajete, 2000) as they named stakeholders. For instance, when one teacher asked, “Well, don’t commuters benefit from the train?” a student responded, “People, commuters, can get to work, or where they are going fast but their neighborhood is not happy, it will be littered and have less trees.” In all three classes, students made consistent moves to trouble the colonial, onto-epistemic stance of technological and economic progress, pushing back against naming stakeholders such as tourists, banks, and businesses along the train route without caring for and discussing complex relational entanglements each stakeholder posed. Eventually, this battle of wills came to an impasse, with students leveraging their power and rights of disengagement to counter the teachers’ power as the instructors. If we consider the learning space to be like a property, students’ disengagement in discourse reflected silent, sit-in protests which commonly occur in settler spaces as brave acts of resistance and refusal. Mirroring these acts, students, once again, turned to the chat space to voice their ideas about stakeholders and their relational reasoning for identifying stakeholders. (see Figure 3)

Figure 3. Student discussion in online chat space

 <p>“If it’s gonna remove a forest or even part of the forest that would still be a great loss because they make oxygen and eat carbon dioxide.”</p>	 <p>“If humans need trees and nature would they be a stakeholder? For kids that want oxygen for their lives maybe?? What do you think?”</p>
 <p>“It might be VERY noisy”</p>	 <p>“Marine biologists will be sad if the waters are polluted because they study the life of marine animals and if the water is polluted they won't be able to.”</p>

Students’ commitment and determination to engage in relational epistemologies while considering stakeholders in the train’s development resulted in teachers relinquishing the structure of the lesson by allowing students to engage in relational reasoning as they identified stakeholders. This rupture of classroom dynamics led to a profound (re)placing and (re)storying of the standardized engineering education storyline with one that embraced complex relational entanglements and socio-ecological realities, centering students’ onto-epistemic knowledges and ways of knowing while also spurring teachers’ critical reflection and flexion.

As a result of students' resistance and determination and the critical reflection and flexion

of the teachers in the study, the stakeholder lessons were expanded to include an activity to invite stakeholders to an imagined design meeting stakeholders. The design meeting invitation lesson was created to help students continue to speculate about who essential stakeholder decision makers would be to determine the future of the train. The outcome of the stakeholder design meeting invitation lesson expanded the engineering learning to illuminate the multispecies LandAirWaterStars kindred relationality present in all engineering endeavors.

Analysis of all 64 student design meeting invitations resulted in 58% of the invitations prioritizing Animals, Land, Water and Trees as essential stakeholders. Of the remaining responses, 33% went to farmers, highlighting students' valuing of community and the relationship between farmers, Land and nearby Waters, and 9% were addressed to citizens, government officials, scientists or engineers, with invitations being framed as critiques or challenges to their presumed stance of the train development. By integrating lessons designed to value and center students' constellar knowledges and ontological security, the classroom learning space transformed. How this transformation unfolded provides insights into how students' resistance and refusals call out and call into light dominant, settled, pedagogical practices and epistemologies, which foreclose expansive and complex future-facing thought.

Further analysis of the design meeting invitations provide researchers, educators and the field of engineering with students' socio-ecological logics for radical caring in engineering. Students' socio-ecological logics posit a worlding (Haraway, 2015) agenda and approach to engineering, shifting the purpose of design and development of human-doings and being to be in right relationship multispecies and LandAirWaterStars kin for living reciprocally and harmoniously.

Discussion: Childrens' Just Worlding Design Principles

Students' socio-ecological logics for radical care in engineering for just worlding are presented in the following section, organized by engineering principles that arose from students' stakeholder design meeting invitations.

Design Principle 1: Honoring kindred relationality as design priority

Analysis of students' invitations illuminated their radical care for worlding technoscientific design as being grounded in the worlding premise that humans and more-than-human species and entities are intimately connected socio-ecologically, through time and space. For students, *knowing* of these relational entanglements seemed to be a core ontological orientation of rightful kinship, leagues away from settler processes of human supremacy. Radically caring for kinship presented the lifeways and affective and intellectual complexities of non-human actors living alongside humans, and in consideration of humans. Naming commitments toof radically caring kinship is evident in the following transcript of a student's stakeholders design meeting invitation:

[To: Landscape] I just received info that a certain train is being built around your border. I wld like you & I to meet to state your concerns and your ideas to make this train better for you and all your subjects. I will give you the intel for the ups & downs of this train. I would also like you to bring 2 or 3 of your subjects to state their concerns for other things you would like to change. Please tell us if you will be joining us, where and when. We live around the train, we don't know what to think, so you are the decider. PS: We are here for you. We are not against you, as others have been in the past.

This example of a stakeholder invitation uniquely models radically caring commitments of

kinship, in that this invitation was co-authored by friends that were inspired to not only write their own invitations, but also felt moved to express their solidarity of and for kinship. These kinfolx also demonstrated their collective *knowing* of entangled and interdependent connections while storying the complex life-ways and life-beings in a perspective-taking invitation response co-create by 3 students who decided to meet over zoom to partner on an invitation response their respective stakeholders- the Landscape, Professor Owl and Elky the “scientific mind.”

[Response from Landscape, Owl & Elk] I am pleased to say that your invitation was received. I will bring my councilman, the Principal of Owlty, "if you send your kids here they won't just get a great education but they will be treated like royalty." His name is Professor (when you address him, always say professor) Owl; and my sister's.....Elky, the scientific mind of my life. Elky will represent our concerns and the public eye. Professor Owl will represent our ideas to improve and help, the world and I will represent the bond between Earth and humans.

Students’ narration of Land, Owl and Elk situates nonhuman animals as *embodied individuals* with a stake in the design (Houston, Hillier, MacCallum, Steele and Byrne, 2018) and Land as a sentient being. This positions them not only alongside humans, but as radically caring kin committed to the cooperative nurturing and educating of “kids.”

What broken-builtness of education, engineering and human centrism can be repaired, restored and (re)imagined if our minds and proverbial hearts are *learned up* by the timeless knowledge(s) of LandAirWaterStars and multispecies? Puig de la Bellacasa asserts, “We must take care of things in order to remain responsible for their becomings” (2017). How does this apply to our youth? For what becomings of our youth do colonial ways of teaching and living represent tragic un-becomings? In other words, which students’ invitations present themselves at

the intersection of radical and holistic becoming and un-becoming in relation to the indoctrination of colonial matrices and reconfiguring of human-LandAirWaterStars-Multispecies relations? The radical caring of kinship elevated in students' stakeholder invitations offer insight into worlding processes that prioritize relationality, for collective continuance (Whyte, 2018)

This invitation (and the other invitations) from students is not only an invitation to the Land, Owl and Elk. It is an invitation to for us as educators, as designers, as kin, to engage in *becoming worlds* that (re)storying and (re)place radically caring for multispecies and LandAirWaterStars kin at the heart of education, technoscientific design and development and within ourselves.

Design Principle 2: Critical & liberatory presencing of multispecies, LandAirWaterStars & rights of nature

It has been established that the influence of settler colonialism's epistemologies of human supremacy, which maintains nature/culture divisions, has resulted in a lack of empathy and care among technoscientific designers in the field of engineering and the education of science and engineering (Gunckel and Tolbert, 2018). If we ponder the question, *At what point on the pathways of life and learning does empathy and care get replaced?*, we may find ourselves within the walls and spaces of "civilized" institutions such as school. The critical liberatory presencing of multispecies and LandAirWaterStars by students in their invitations offer a rights and justice-forward approach towards empathetic, radically caring design and development.

In the following example, the student situates Mr. Peckie, the Woodpecker within the geography of the train, as an agentic being, reflective of place-thought, and not only capable of providing guidance to inform technoscientific designs but also holding necessary placed and relational experiential expertise. Additionally, this example, as was true in other examples, is

evident of how the content learned during the engineering critical research lessons was leveraged during the stakeholder design meeting invitations culminating lesson.

[To Mr. Peckie the Woodpecker] When we build this train we will have to cut down many trees in your habitat. We will also have to pollute wildlife water supplies in order to build the train. We have some questions for you too! First, how crucial are the trees that you live in? Second, are mountains important to your ecosystem? Third, are you okay with finding a new home? Fourth, where do you get your fresh water supply? Fifth, why did you choose to live here? Lastly, are you okay with this natural habitat being destroyed (maybe not) probably though forever?

The presencing of Mr. Peckie the Woodpecker as rights-full is evident in the fact that the line of inquiry infers that the train will destroy the Woodpecker's habitat impacting his (gender implied by student) right to live and be in thriving relations with clean water, wildlife, mountains and trees. By understanding and elevating the inter-intraconnectedness of Mr. Peckie, multispecies, trees, mountains and waters, this student materializes the embodied lifeways that will unjustly be harmed, reduced to collateral damage for colonial definitions of progress and eco-logics of mobility. This student presences the rights of the would-be-erased, displaced, unknown and never-to-become by radically caring about the survivance and thriving of the Woodpecker's web of life. This radical care situates the design of the maglev train within the entanglement of multispecies and ecological justice and technoscientific development. Additionally, this student counters humanism in engineering through a presencing of multispecies justice and rights framing that values Mr. Peckie the Woodpecker's experience and input as central to deciding if and how the train should be developed. This student example is representative of the 58 of the 64 stakeholder design meeting invitations, which all propose the radical caring of multispecies and ecological justice by foregrounding the rights and critical

liberatory presence of stakeholders for worlding just worlds. Of the six that did not directly name a multispecies and/or LandAirWaterStars stakeholder, five directly named human roles they believed to have power to make decisions about the train being developed, and one student named a Martian as a stakeholder.

Design Principle 3: Transparency & humility as a valued design stance

Aligned with, and in support of the three other design principles, the call for engineering and settler transparency and humility counters anthropocentrism, which enables the fallacy that humans are the most significant entity on the planet resulting human domination-over all multispecies and LandAirWaterStars sentient entities. The following two transcripts of student design meeting invitations model engineering practices of transparency and humility to set a trajectory for just design and development while inviting methodologies of resistance and refusal.

[To: Oi River & fish] We are making a maglev train in Japan and we are building it because it will be twice as fast as the old train. We are notifying you because it may pollute the Oi river. We request that you help us create alternate tracks. We need you to come bc nobody can better help us find safe paths then somebody that lives in the Oi river and depends on it. You will give us a very new perspective because everybody else is a human. Do you already have other ideas for paths? Do you think we should cancel the whole idea? By the way, you may bring other animals and plants.

This student example models a practice of foregrounding transparency and humility in technoscientific development with the statement, “We are building it because it will be twice as fast as the old train,” followed by, “We are notifying you because it may pollute the Oi river.”

On the surface, this would seem a simple declaration of fact. However, the student provides a model of transparency for engineering as well naming potential socioecological impacts. By stating the motive for developing the train first, followed by informing the stakeholder how they may be impacted, this student radically challenges the anthropocentric dynamic of settler colonial methods of engineering. They do so first by elevating the river and fish as equal or perhaps superior beings to humans. Second, communicating and radically caring about the harm(s) caused by development is drastically counter to settler eco-logics of mobility perpetuated in industrial engineering, which minimize environmental impacts and/or take a hindsight mode that sees these impacts as an inevitable and worthy cost of progress. Kristin Gunckel and Sara Tolbert call out the support for these settler eco-logics of mobility and minimization of harm done to nature in the NGSS, engineering education standards and NRC Framework. They state that “by suggesting that design can solve any problem that people want to change, the *Framework* and NGSS perpetuate the technocratic myth that societies can engineer themselves out of all complex and thorny situations without addressing the underlying human dimensions that create the problems in the first place” (2018, p. 5).

The following student stakeholder invitation shows how engineering can counter dominant and enabled stances of human exceptionalism, arrogance, and practices of deception. Leveraging their original intuition, this student provides anti-settler eco-logics of transparency and humility that are visceral and palpable, using affective prose to urge rural farmers to attend the stakeholders design meeting.

[To: Farmers] We want to talk to you because we have a problem. I think you should come because you are a stakeholder and we are making an impact in your environment. The impact is that we are building a massive train. Of course before we release it we

want to talk to all the stakeholders. So we really want to talk to you so we can make a decision. Now why we want you is because we want others perspectives, not just ours. We want some others' perspectives bc if we don't have other perspectives, then a lot of people will be against us. We have a few questions. That you should answer. We think we have the answer to this one but will you be fine if your crops are ruined? Probably not. Well another question is do you like noise right next to you because our train will have a lot of noise and cost a lot. Anyway that is all we wanted to ask and I hope you will share your ideas.

Humility counters westernized positivism in science and engineering which tout technoscientific innovations as universally beneficial. Humility is not synonymous with weakness, shame, or powerlessness. Rather, according to Tiokasin Ghosthorse, “We can be humbled by addressing our grief. We can be humbled by addressing that maybe we've done a little too much with technology. We made that our savior. Maybe we've done a lot of things that we should have never done” (Young, 2021, 57:30). Students’ narratives of humility restructure power by positioning community and ecological entities as resources of expert and necessary knowledge. In the example of the Oi river and fish, when the student writes “We need you” and to asks them to “bring other animals and plants,” the humility expressed is not to be diminished as childish innocence, but rather a powerful knowing of missing relational epistemologies and ontological intuitions (Young, 2021, 4:07) that are necessary to (re)member and (re)imagine ways to (re)design structures and learning to be radically caring.

Design Principle 4: Resistance and refusal as valued design practice

Throughout this study, students fundamentally asserted the need to axiologically (re)story sociotechnical design and development towards radical care for a futurity in peril, futurities

denied and a futurity of becoming-with worlds (Haraway, 2015). As indicated, this means that engineering and engineering education need to be unsettled by prioritizing principles of reciprocal kinship and establishing design criteria and practices that prioritizes the critical liberatory presencing of multispecies communities and LandAirWaterStars for socioecological justice. Such a (re)story would be revolutionary, as it materializes an ongoing design stance of resistance and refusal if development is determined to be unjust. This runs contrary to one of the teacher's perceived ideological struggle during instruction, summarized in their positivist comment, "I have to hold onto the belief that science, scientists and engineers are always trying to do good." Instead, students maintained that science and engineering endeavors must prove they are just and are always at risk of being disrupted and/or denied. Clarity of this stance of resistance and refusal is evident in the following two student design meeting invitations and narrated responses.

[To: Environmentalist] You have been invited here to look at this train in your own perspective. It is a long maglev train that runs along beaches & forests. This meeting is important because we want to know a new view on helping the environment. I hope you can tell us what would be good for the people and the Earth. These are some questions for you to answer: What would this train do to hurt the environment and what can we do to help it? What can we do to help stop noise pollution? Thank you

[Response from Environmentalist] Destroying the forests and habitats for this train is selfish and absurd.

[Response from Sacagawea, "a revered cultural leader"] I know a lot about the land so if you want to hear my opinion come ask me! I am wise but I do not consider myself old, I am only 60. I would like to share my opinion to everyone to hear because I know alot

about the train and land!!! Though I am not used to modern things. Also I know a lot about the train from listening to train builders! I say No train! The land says to me that the mountain is calling for help, the forest too and the people are literally calling for help saying it will pollute the water, the mountain should not get hurt which is true.

In the first example above, the student sets up the environmentalist to provide information to substantiate the resistance and refusal of the train's development by admitting that a counter perspective is needed to determine “what would be good for the people and the Earth” and “what can we do to help stop noise pollution?” The student then offers a demonstrative resistance and refusal from the environmentalist, stating, “*Destroying the forests and habitats for this train is selfish and absurd.*” In the second example, the student takes on the perspective of a revered cultural leader as protector of and speaker for the land, mountain, forest, water and people, refusing the development with the statement “*I say No train!*” Such powerful stances of refusal reflect antiracist and liberatory feminist approaches to engineering, in which “a creative solution is sought to benefit all community members, with the participation of all concerned, and proposed solutions are evaluated based on their contribution to the goal of social justice, recognizing that sometimes the best solution may be not to engineer in the first place” (Riley et.al., 2009, p. 33). Students’ ongoing resistance and refusals of unjust development offer wise guidance to help ensure that technoscientific design agendas are oriented towards justice through radically caring engineering practices.

The instructional design of the stakeholder design meeting served to scaffold solidarities, as evident in above student examples, as well as scaffold opportunities for dissent to complexify and open up multiple perspectives, desettling authority and engineering norms. In the following invitations, students engage in a mode of questioning that asks figures of systemic authority to

set up opportunities for other stakeholders to critique and challenge the authority figures' value stances and potential alignment with settler eco-logics.

[To: President of country] My question is do you think it will be worth the money and all the cons? Do you really want to hurt nature?

[To: Scientists] Train will hurt the environment and animals, but it will be better than cars, are you okay with this?

[To: Mayor] You are invited because we need to discuss why you are building the train.

[To: Engineer] Discuss train's cost, space & animal environments. They destroy plants & damage electricity lines...can you make trains take less space and can you make it impact less?

Students' critical questions posed to humans in understood positions of power act to level the playing field, so to speak, dismantling hierarchical, structural boundaries and barriers that perpetuate injustice by advancing hidden agendas of colonial progress (e.g., through development projects). Students' refusal to naively trust and respect those in roles of authority as agents of ethical and just leadership maps ontological distances and locations between pre-colonized and colonized mindsets. By centering engineering practices of resistance and refusal, humility and critiquing of neoliberal, utilitarian and capitalistic agendas, students were challenging and "delinking... from the colonial matrix of power" (Mignolo, 2009). Ontological and pedagogical shifts that position students as co-constructors and co-designers of place and technology, void of preconceived notions and constraints of engineering, resulted in students manifesting revolutionary new ways to embark on engineering endeavors.

Table 1. Just worlding design principles with additional examples of student invitations

Design Principle 1: Radical Care of Kindred Relationality as Design Priority	Design Principle 2: Critical & Liberatory Presencing of Multispecies, LandAirWaterStars & Rights of Nature	Design Principle 3: Transparency & Humility as Valued Design Stance	Design Principle 4: Resistance and Refusal as Valued Design Practice
[Trees] I want to invite the trees because trees are impacted by trains going through forests. Trees have to be cut down when trains go through forests. A perspective they might share is that trees are important to the ecosystem because they provide homes for animals & clean the air so when trees get cut down it hurts not only the tree but also the animals.	[Animals affected by train & an animal translator] They are being invited because their homes might be destroyed and could get killed also the animal translator because how are [we] going to be able to understand them. It's important they come so we can talk about clearing out their homes and stay out of the way. Animal translator so they can understand each other. I hope they are so cute that they change the route of the maglev train so that it will not go into their homes. 2 questions I want them to answer are if they are okay with us blowing up their homes and how does an animal translator understand the animals?	To Mr. Willy the Mountain, you are being invited to the annual Maglev revision day. This Maglev will be cutting through part of your body. We will interview you on how you would like to revise this Maglev. We hope you share your ideas with us. Some questions we might ask you are: 1. Do you like this train, if so, why do you like it? 2. If you had to change this train, how would you do it and why?	[Trees] I have invited you to help us at the N.S.C. (Nister Science Co.) to make it [the train] better for you and your family. To tell you about this train, it runs at a speed of 168mph. Please come because we need your help to design it, and way more, I hope you will tell them not to break forests. You will have to answer two questions. 1. why you came to the meeting? 2. what do you want to change for this train?
[Squirrels] We think it may hurt the environment, we would like to know how you think of it. PS the birds will be there to discuss importance of trees	[River] You are invited to discuss problems of the Maglev train, one reason you should come is to make it better and it affects your problems. We want to talk about how you think we should fix your problems.	[Citizen] Share what you don't like about the train. Do you think it is too expensive? We think we need your permission. You should know it will help people get to work fast but it is bad for the environment.	[Fishy] You will give us a very new perspective because everybody else is a human. Do you already have other ideas for paths? Do you think we should cancel the whole idea? By the way you may bring other animals and plants.
Dear Luna & Midnight, (Wolves) Please attend this design meeting for the train. It would make this meeting so much better if we heard your & your pack's ideas. What do you think we should add, and what should we remove?	[Trees, Waterfalls, Rivers] You are being invited because the train is going to impact you guys!! Yay, Wa-hoo you guys are going to help us with how to make the train better, the train is going to be cutting through some farmland and will be near some ppl and ppl will have to blow up nature. Please help to come up with some ideas to save you!	[Farmers] We want to talk to you because we have a problem. I think you should come bc you are a stakeholder and we are making an impact in your environment. The impact is that we are building a massive train. Of course, before we release it we want to talk to all the stakeholders.	I think Mr. Animal should join bc he is rooting for the trees to stay alive and he thinks that his home will be destroyed because of the mountain [being blown-up] he will answer the questions where his home is in the forest and why he thinks that the train idea should be terminated!

Implications: (Un)Learning and (Un)(Re)Becoming With and For Children

As we sink deeper into students' invitations, a foreboding narrative arises of becomings that never became or may never become. As educators, as adults, how and what have we (un)become as actors of settler colonialism? What ghosts of ourselves and youth do we unwittingly create when we perpetually require and standardize settler progress narratives and epistemologies that sacrifice student's ontological security and intellectual health? How can we (un)(re)become with ourselves, with youth and with LandAirWaterStars and multispecies that worlds a new otherwise.

By humbly sitting alongside students, as equals, and understanding the on-going, new and yet-to-be challenges they are witnessing and facing, educators, curriculum designers and writers of standards have much to (un)learn and take critical response-ability (Kayumova &

Tippins, 2021) to address. Reflecting this understanding, this study leveraged the Critical Speculative Design Pedagogies framework to create lessons to counter the false narrative of a neutral curriculum and neutral instruction, understanding that “washing one's hands of the conflict between the powerful and the powerless means to side with the powerful, not to be neutral” (Freire et al., 1985, p. 122). Through this decision, but more so through the honest and necessary strength and brilliance of the youth, those of us in engineering education have been given a gift of insight into not only what can be but what should be. In truth, “The time for arguing for a socio-politically engaged and transdisciplinary science education for multispecies survival is effectively over” (Wallace et al., 2022, p. 4). The youth are waiting for us educators to desettle our own onto-epistemic selves, engage in critical reflection for critical flexion and step up to do so in science and engineering curricula in all learning spaces.

This study also illuminates, through the resilience, resistance and refusals of third grade students, a new and urgent approach to science and engineering education that not only embraces multispecies and LandAirWaterStars justice for collective continuance, but does so while exceeding learning standards in complexity and praxis. Given the pace of socio-ecological harm occurring due to settler eco-logics of progress, it is time for NGSS, the NRC *Framework* and all engineering standards to be anti-colonial, generationally competent and radically caring. Movement towards this belated need can and should be guided by the four design principles of engineering that the students in this study provided.

The four design principles of, *honoring kindred relationality as design priority, critical & liberatory presencing of multispecies, LandAirWaterStars & rights of nature, transparency & humility as valued design stance, resistance and refusal as valued design practice*, provide engineers, the field and education of engineering new and urgent design and development

priorities and practices. As has been mentioned, engineering has for too long been a field that has actualized and materialized colonial plans of socio-ecological consumption and dominance. The design principles that the youth in this study offer provide the field a heart, a pulse within cyborgs and cyborg-making practices, not only capable of empathy but also new, creative Landscapes for dreaming and developing, “critical for developing climate-adaptive planning tools and narratives for the creation of socially and environmentally just multispecies cities” (Houston et al., 2018, p. 191).

Conclusion: Designing Beyond ‘Situation Critical’ Towards Kincentric Flourishing

What is the world beyond coloniality and human supremacy? What worlds can we (re)imagine and (re)generate through the dissolution of the tendrils of settler eco-logics in our minds, classrooms, and technoscientific innovations? Designing for worlds of multispecies flourishing requires radical caring that foregrounds the socio-spatial histories and futures of LandAirWaterStars and multispecies and positions humans as agentic beings for collective flourishing, as best we can. This means that the planning, (re)designing and (re)development of all spaces must prioritize the well-being of more-than humans, humans and LandAirWaterStars through relational and reciprocal epistemologies. Youth ontologies and logics of radical care asserted in this study offer alternative worlding and multispecies justice frameworks for engaging in this urgent work within the fields and education of engineering and planning theory. Planning and designing for socio-spatial justice means disrupting settler conceptions of progress that betray and deceive us (Kayumova, McGuire & Cardello, 2019) and illuminating the points of convergence of relational complexities between humans, multispecies and LandAirWaterStars, not as points of divergence, but as points for expansive radical care needed for (re)imagining an *otherwise*.

To (re)make these endeavors requires centering educational experiences and research outside the confines of reductive, dominant science and engineering lessons. Learning opportunities can be created to expand and contribute pedagogies and methodologies that reconfigure power and purpose to promote new imaginings of engineering for collective continuance—the culturally-grounded, moral pursuit of rightful relations (Whyte, 2018). Providing students with an authentic and consequential place-based context had the power to disrupt the onset of colonial mindsets and illuminate the foolishness and short-sightedness of settler colonial eco-logics.

Considering “discipline is empire” posits pedagogies and standards as epistemic borders that close horizons of expansive learning and being (McKittrick, 2021, p.36). To move beyond these boundaries and epistemic supremacy, this design-based research purposely embedded learning engagements aligned to multiplicity, horizontality, and dialogicality—the three dimensions of radical heterogeneity within the westernized classroom spaces and curriculum (Warren et al., 2020). This unit situated the curricular phenomena of a maglev train outside the enclosures of settled science and technocratic engineering design cycles and instead moved it into global socio-ecological Landscapes and realities. As a result, westernized knowledges and practices were no longer positioned as singular and supreme, opening space for multiplicity by inviting multispecies, community, LandAirWaterStars knowledges. The desettling of westernized disciplinary frames opened up space to provide dialogicality through engagements of perspective-taking for meaning-making and created “a critical site of refusal, delinking, and re-imagining the normative chains that structure disciplinary learning.” (Warren et al., 2020, p. 285)

The recognition and respecting of students, marginalized community members,

multispecies and ecological entities as critical actors in technoscientific decision-making provided scaffolds for epistemic disobedience and the re-storying and repurposing of engineering goals to be grounded in radical care for worlding common worlds (Nxumalo & Pacini Ketchabaw, 2017). As educators and radical individuals, “We cannot continue to build a world on the backs of children while denying their right to live in it” (author unknown). Disrupting settler colonialism in science and engineering education means demanding standards and practices that bring in multispecies justice frames for kincentric flourishing.

References

- Arada, K., Sanchez, A., & Bell, P., (2023). Youth as Pattern Makers for Racial Justice: How Speculative Design Pedagogy in Science Can Promote Restorative Futures through Radical Care Practices. *Journal of Learning Sciences*
- Bang, M., Warren, B., Rosebery, A. S., & Medin, D. (2012). Desettling expectations in science education. *Human Development*, 55(5-6), 302-318.
- Bang, M. (2017). Towards an ethic of decolonial trans-ontologies in sociocultural theories of learning and development. *Power and privilege in the learning sciences: Critical and sociocultural theories of learning*, 115-138.
- Bang, M. (2020, June 11). *Two Feathers: Native Science and Student Wellness* [Video]. Youtube. <https://www.youtube.com/watch?v=5qgTxPOSFag>.
- Bang, M., & Marin, A. (2015). Nature–culture constructs in science learning: Human/non-human agency and intentionality. *Journal of Research in Science Teaching*, 52(4), 530-544.
- Cajete, G. (2000). *Native science: Natural laws of interdependence*. Santa Fe, NM: Clear Light Publishers.

Charmaz, K. (2001). Grounded theory. In R. M. Emerson (Ed.). *Contemporary Field Research*, (pp. 335-- 352). Long Grove, IL: Wavela

Claris, L., & Riley, D. (2012). Situation critical: critical theory and critical thinking in engineering education. *Engineering Studies*, 4(2), 101-120.

Denzin, N. K., & Lincoln, Y. S. (2005). *The Sage handbook of qualitative research*. London, Stage Publication.

Dietrich, R. (2016). Made to Move, Made of this Place: *Into America*, Mobility, and the Eco-Logics of Settler Colonialism. *Amerikastudien/American Studies*, 507-525.

Espinoza, M. L. (2008). *Humanization and social dreaming: A case study of changing social relations in a summer migrant educational program*. University of California, Los Angeles.

Espinoza, M. L., & Vossoughi, S. (2014). Perceiving learning anew: Social interaction, dignity, and educational rights. *Harvard Educational Review*, 84(3), 285-313.

Frausto Aceves, A., Torres-Olave, B., & Tolbert, S. (2022). On love, becomings, and true generosity for science education: honoring Paulo Freire. *Cultural Studies of Science Education*, 17(2), 217-230.

Freire, P., Giroux, H. A., & Macedo, D. P. (1985). *The politics of education: Culture, power, and liberation*. South Hadley, Mass: Bergin & Garvey.

Gunckel, K. L., & Tolbert, S. (2018). The imperative to move toward a dimension of care in engineering education. *Journal of Research in Science Teaching*, 55(7), 938-961. <https://doi.org/10.1002/tea.21458>

Haraway, D. J. (1991). A Cyborg Manifesto: An ironic dream of a common language for women in the integrated circuit. In *The Transgender Studies Reader Remix* (pp. 429-443). Routledge.

Haraway, D. J. (2015). Anthropocene, capitalocene, plantationocene, chthulucene: Making kin. *Environmental humanities*, 6(1), 159-165.

Haraway, D. J. (2016). *Staying with the trouble: Making kin in the Chthulucene*. Duke University Press.

Hobart, H. J. K., & Kneese, T. (2020). Radical care: Survival strategies for uncertain times. *Social Text*, 38(1), 1–16. <https://doi.org/10.1215/01642472-7971067>

hooks, b. (2013). *Teaching Critical Thinking: Practical Wisdom*. Routledge

Houston, D., Hillier, J., MacCallum, D., Steele, W., & Byrne, J. (2018). Make kin, not cities! Multispecies entanglements and ‘becoming-world’ in planning theory. *Planning Theory*, 17(2), 190–212. <https://doi.org/10.1177/1473095216688042>

Jones, K. & Okun, T. (2001). White supremacy culture. *Dismantling racism: A workbook for social change*.

Kayumova, S., McGuire, C.J., & Cardello, S. (2019). From empowerment to response-ability: rethinking socio-spatial, environmental justice, and nature-culture binaries in the context of STEM education. *Cultural Studies of Science Education*, 14, 205-229.

Kayumova, S., & Tippins, D. J. (2021). The quest for sustainable futures: designing transformative learning spaces with multilingual Black, Brown, and Latinx young people through critical response ability. *Cultural Studies of Science Education*, 16(3), 821-839.

Latour, B. (2004). How to Talk About the Body? the Normative Dimension of Science Studies. *Body & Society*, 10, 205 - 229.

McGowan, V., & Bell, P. (2020). Engineering Education as the Development of Critical Sociotechnical Literacy. *Science & Education*, 1-25.

McKittrick, K. (2021). The smallest cell remembers sound. *In Dear Science and Other Stories*. Duke University Press.

Medin, D. L., & Bang, M. (2014). *Who's asking?: Native science, western science, and science education*. MIT Press.

- Mignolo, W. D. (2009). Epistemic disobedience, independent thought and decolonial freedom. *Theory, Culture & Society*, 26(7–8), 159–181.
- Miles, M. B., Huberman, A. M., & Saldaña, J. (2014). Chapter 4: Fundamentals of Qualitative Data Analysis, pp. 69-100. In Authors, *Qualitative data analysis: A methods sourcebook* (3rd ed.). Los Angeles, CA: SAGE Publications
- Miller, E., Manz, E., Russ, R., Stroupe, D., Berland, L. (2018). Addressing the epistemic elephant in the room: Epistemic agency and the next generation science standards. *J Res Sci Teach.* 1– 23. <https://doi.org/10.1002/tea.21459>
- Mitchell, A., & Chaudhury, A. (2020). Worlding beyond ‘the’ ‘end’ of ‘the world’: White apocalyptic visions and BIPOC futurisms. *International Relations*, 34(3), 309-332.
- National Research Council. (2013). Next generation science standards: For states, by states.
- Nxumalo, F. (2015). Forest stories: Restorying encounters with “natural” places in early childhood education. In *Unsettling the colonial places and spaces of early childhood education* (pp. 21-42). Routledge.
- Nxumalo, F. (2016). Storying practices of witnessing: Refiguring quality in everyday pedagogical encounters. *Contemporary Issues in Early Childhood*, 1–15. <https://doi.org/10.1177/1463949115627898>.
- Nxumalo, F., & Pacini-Ketchabaw, V. (2017). “Staying with the trouble” in child-insect-educator common worlds. *Environmental Education Research*, 23(10), 1414–1426. <https://doi.org/10.1080/13504622.2017.1325447>
- Nxumalo, F. (2018). Stories for living on a damaged planet: Environmental education in a preschool classroom. *Journal of Early Childhood Research*, 16(2), 148–159. <https://doi.org/10.1177/1476718X17715499>
- Philip, T. M., Bang, M., & Jackson, K. (2018). Articulating the “how,” the “for what,” the “for whom,” and the “with whom” in concert: A call to broaden the benchmarks of our

scholarship. *Cognition and Instruction*, 36(2), 83-88.

Puig de La Bellacasa, M. P. (2017). *Matters of care: Speculative ethics in more than human worlds* (Vol. 41). U of Minnesota Press.

Puig de la Bellacasa, M. (2011). Matters of care in technoscience: Assembling neglected things. *Social Studies of Science*, 41(1), 85-106.

Pugh, P., McGinty, M. & Bang, M. (2019). Relational epistemologies in land-based learning environments: reasoning about ecological systems and spatial indexing in motion. *Cultural Studies of Science Education*, 14(2), 425-448.

Riley, D., Pawley, D.A., Tucker, D.A., & Catalano, D.A. (2009). Feminisms in Engineering Education: Transformative Possibilities. *NWSA Journal*, 21, 21 - 40.

Sanchez, A. (in press). The Social Focus Framework: Anti-racist and Anti-colonial conscientization, consequence and presencing in science education. In S. Tolbert, M. Wallace, M. Higgins, & J. Bazzul (Eds.) *Reimagining Science Education in the Anthropocene: Volume II*. Cham: Palgrave Macmillan

Sailiata, K. (2015) Decolonization. In Raheja, M., Smith, A., & Teves, S.N., (Eds.) *Native Studies Keywords*.(pp. 301-308) Tucson: University of Arizona Press.

Strauss, A., & Corbin, J. (1998). *Basics of Qualitative Research: Techniques and procedures for developing grounded theory*. Thousand Oaks, CA: Sage.

Taylor, A., & Pacini-Ketchabaw, V. (2018). *The common worlds of children and animals: Relational ethics for entangled lives*. Routledge. 10.4324/9781315670010.

Tuck, E., &ocollet, K. (2016). " EJ" in Focus: Introduction to Native Feminist Texts. *The English Journal*, 106(1), 16-22.

Tzou, C., & Bell, P. (2010). Micros and Me: Leveraging home and community practices in formal science instruction. In K. Gomez, L. Lyons & J. Radinsky (Eds.), *Learning in the Disciplines: Proceedings of the 9th International Conference of the Learning Sciences Volume 1* (pp. 1134-1142). Chicago, IL: International Society of the Learning Sciences.

Vossoughi, S., Davis, N. R., Jackson, A., Echevarria, R., Muñoz, A., & Escudé, M. (2021). Beyond the Binary of Adult Versus Child Centered Learning: Pedagogies of Joint Activity in the Context of Making. *Cognition and Instruction*, 0(0), 1–29.

<https://doi.org/10.1080/07370008.2020.1860052>

Watts, V. (2013). Indigenous Place-Thought and Agency Amongst Humans and Non Humans (First Woman and Sky Woman Go On a European World Tour!). *Decolonization: Indigeneity, Education & Society*, 2(1), 20-34.

Need citation: Wallace, Bazzul, Higgins & Tolbert, 2022, p. 4

Warren, B., Vossoughi, S., Rosebery, A. S., Bang, M., & Taylor, E. V. (2020). Multiple ways of knowing*: Re-imagining disciplinary learning. In *Handbook of the cultural foundations of learning* (pp. 277-294). Routledge.

Whyte, K. P. (2013). Justice forward: Tribes, climate adaptation and responsibility. In *Climate Change and Indigenous Peoples in the United States: Impacts, Experiences and Actions* (pp. 9-22). Cham: Springer International Publishing.

<https://doi.org/10.1007/s10584-013-0743-2>

Whyte, K. (2018). Settler Colonialism, Ecology, and Environmental Injustice. *Environment and Society*. 9. 125-144. 10.3167/ares.2018.090109.

Wolfe, P. (2006). Settler Colonialism and the Elimination of the Native. *Journal of Genocide Research* 8.4 : 387– 409.

Young, A. (Host). (2021, June 9). Tiokasin Ghosthorse on the Power of Humility (No. 237) [Audio episode podcast]. In *For the wild*

<https://forthewild.world/listen/tiokasin-ghosthorse-on-the-power-of-humility-237>

Conclusion: Toward a District-Level Multiscalar Approach to Engaging Young People in Critical Speculative Design

“The future is not some place we are going, but one we are creating. The paths are not to be found, but made. And the activity of making them changes both the maker and the destination.”

— John Schaar

Change is inevitable, as the future unfolds as a global society we will all endure the changes we are on track to experience. However, we still have time to intervene to choose more than a colonial default future, we still have the opportunity to thread, weave and pattern a liberatory future, a created future that we can all get behind that prioritizes the eco-relational matter and mattering of all Earthly kin. We must first critically see what is unsustainable and then boldly and bravely intervene, particularly considering as a collective we are already living and dying in the chaos of climate change. In effort to provide a substantial understanding about how to contribute to our collective continuance my dissertation research elevates liberatory design principles that center teachers rogue pathways of (un)learning and action, and childrens’ critical eco-relational mattering of Othered, essential earthly kin and the radical caring worlding of their worlds already being compromised.

Liberatory and Thriving Futures are at Stake

Recently, the Smithsonian Science Education Center partnered with Gallup to conduct a survey study with teachers, administrators and students across Brazil, Canada, France, India, and the

United States regarding the inclusion of the United Nations' Sustainable Development Goals (SDGs) (UN, 2015) into formal education, with an emphasis on science education. (2023)The 17 SDGs “recognize that ending poverty and other deprivations must go hand-in-hand with strategies that improve health and education, reduce inequality, and spur economic growth – all while tackling climate change and working to preserve our oceans and forests.” (UN, 2015) The report indicated substantial variability between U.S. teachers compared to their counterparts in Brazil, Canada, France, and India in terms of support, time, and expertise to incorporate sustainable development into their teaching. Notably, U.S. teachers are three times less likely than those in the other countries to report having the necessary support to integrate sustainable development topics into various subjects. The report also highlights that socio-scientific topics related to sustainability are among the least likely to be found in U.S. curricula, with a majority of U.S. teachers indicating that sustainability does not align with the subjects they teach. Only 17% of U.S. teachers feel adequately supported to include sustainable development topics in their teaching, citing challenges such as time constraints, lack of curricular materials, and limited professional development opportunities. (p.6)

Upon initially reviewing the SDG survey report, my immediate response was a resounding, "I am not surprised by the findings." This assertion draws upon a decade-long immersion as a formal science educator, extensive involvement in the educational sector at various scales and as a learning sciences researcher, and a diverse identity intertwining Chicana heritage with Yaqui, Mayan, and Spanish lineage. Simultaneously, my role as a mother navigating the uncertain future of my offspring positions me as someone with "skin in the game" (Mckinney de Royston & Sengupta Irving, 2019, p. 279). In elevating this report within my dissertation conclusion, it transcends mere academic formality; rather, it issues a clarion call to

prioritize the integration of teacher professional development, science education, pedagogical practices, and student learning within consequential eco-relational sustainability contexts and considerations with the unwavering intent to advance antiracism and anticoloniality.

Furthermore, the Social Focus Initiative⁴ guided by the Social Focus Framework (Sanchez, 2024) and the report share a common purpose encapsulated in the disruption and hopeful cessation of the enduring legacy of colonization and white supremacy that underlies all seventeen SDGs. Analogously, they converge by emphasizing the transformative potential of transdisciplinary instruction, advocating for the necessity of curriculum, teaching, and learning to "emphasize the links among engineering, technology, science, and society" (p. 47) as approaches that foster students to be "careful consumers of scientific and technological information related to their everyday lives" (p. 46), two overlooked standards in NGSS proposed by the National Research Council (Zucker & Noyce, 2020)—concepts pivotal to my dissertation's focal objectives.

Deliberate connections are drawn between teachers' reasons for neglecting the SDGs and sustainability topics in their instruction and the key focal objectives of my dissertation research, as highlighted in the report (p. 6). The SDG survey study ultimately reveals a disconcerting reality: education, particularly U.S. science education, not only lags but places future generations in peril concerning the knowledge needed to foster sustainable global leadership. Implicitly, achieving the seventeen SDGs necessitates dismantling and discontinuing colonialism and white supremacy, a realization prompting a call for efforts to "efforts to re-imagine the design,

⁴ The Social Focus Initiative, as an embodied and enacted initiative, has moved across educational spaces, as I have moved within those spaces, yet always remained a steady homeplace of my life's heartwork which this dissertation research is derived from, began in my classroom, alongside my teacher partner, both profoundly disturbed by the disconnect of science content and instruction, the lives, realities of our students and the local, racial, ecological and global consequential on-goings surrounding and impacting them.

enactment, and study of disciplinary learning that take seriously the ‘task of de-colonial thinking’ (Mignolo, 2009, p. 15) and the project of onto-epistemic heterogeneity (Bang & Vossoughi, 2016; Rosebery, Ogonowski, DiSchino, & Warren, 2010).” (Warren et.al., 2020, p. 278) Due to the complex infrastructuring of white supremacy and colonialism within educational structures, multiscale efforts are imperative, spanning sustained time scales and various levels of analysis. (Bell, 2004)

Elements of an Educational Transformation Framework to Engage Youth in Critical Speculative Design

This study was focused on shifting the learning opportunities of elementary students across a school district by building teacher capacity to adapt curriculum to support students’ anti-racist and anti-colonial science and engineering learning. The lines of research I pursued has resulted in the learning and design principles shown in Table 1 in Chapter 1.

Teacher (Un)Learning Pathways Towards Antiracist and Anticolonial Science Education

This dissertation explored the effects of a 15-month professional learning initiative among a cohort of teachers. As reported in Paper 1, an analysis of teacher learning pathways resulted in a typology representing variable patterns of engagement—summarized in these two design principles.

Principle: Dimensions of Whiteness Create Multiple Teacher Learning Pathways

Teachers variably engaged in professional learning focused on antiracist and anticolonial science education. These variations resulted in a variety of more and less desirable pathways of

teacher learning and action. Less desirable pathways of engagement were driven by white innocence, ignorance, saviorism, and arrogance. Nevertheless, many teachers engaged in significant professional learning through the effort—highlighting the developmental nature of critical teacher learning.

In colonial modes of thought, the adult is perceived as a more complete human than the child, a logic grossly ingrained in white supremacy culture that equates humanity with whiteness, especially white, cisgendered maleness, therefore valuing white adult maleness over Others. This ideology is deeply embedded in the fabric of our society, extending to our educational system considering schools mirror society, in turn schools reproduce dominant social thought. Thus the work of promoting antiracism and anticoloniality amongst teachers and their curriculum becomes a design project of unraveling the completed adult human, to reveal the highly capable learner—capable of the rigorous critical un-doing of westernized ways of being and knowing, capable of disrupting their participation in racist educational injustice, capable of healing personal and inflicted colonial trauma, capable of (re)(co)becoming kinfolx, or a closer approximate. This radically caring, albeit ambitious, premise, or high-level conjecture in the world of DBIR (DBIR, Fishman et.al., 2013) is necessarily rooted in critical theory, in particular the critical realism (Bell, 1991) which understands though white supremacy, settler colonialism, and coloniality yield tangible, often deleterious consequences, their status as transient objects⁵ implies they are not absolute truths and need not be inevitable (Whelan, 2019; Bhaskar, 2008).

⁵ In critical realism, a "transient object" refers to temporary concepts, theories, and models used to navigate and understand the world. The term "transient" emphasizes the dynamic and malleable nature of our knowledge, allowing for evolution, challenge and even rejection. Societal issues like white supremacy, settler colonialism, and coloniality are viewed as transient objects in critical realism, acknowledging their real-world impact but recognizing that they are not absolute truths and can be subject to re-evaluation and change. Critical realism posits that social structures, though not always directly observable, have deep causal powers that can be studied to understand, challenge, and ultimately change phenomena in the social world, offering emancipatory potential.

Therefore, these untruths within the teacher and within teaching are not inevitable but require diligent efforts to de-link, deprogram and desettle. Such liberatory considerations thus situate the teacher adult as the (un)learner and learner.

From this perspective, as learning scientists, as educators of educators, with aims of antiracist and anticolonial emancipatory change, teacher (un)learning and learning design considerations take into account varying onto-axio-epistemological developmental levels of socio-ecological relationality, critical consciousness, racism/antiracism, and coloniality/anticoloniality, and socio-emotional well-being. Thereby, necessitating a responsible and responsive arc of (un)learning, sustained over time with these developmental areas being both design commitments as well as units of analysis for iterative redesign.

Understanding critical learning from this (un)learning developmental perspective challenges and counters popularized methods of teacher learning, particularly in the realm of justice, race and equity, opening up potentialities to move beyond methods of dissemination of content for short-term cognitive sensemaking, shifting towards recognizing (un)learning dynamically developmental with learners naturally following variable pathways, with each pathway needing unique supports and scaffolds, engagements and experiences, and timelines.

While my doctoral research endeavored to do just that, however, as is often the case with initiatives seeking liberation within contexts closely tied to, and funded by, the very institutions and individuals requiring antiracist and anticolonial developmental evolution, the support that can be extended is conditional. These conditions hinge upon preserving systems and the comfort and power of those in authoritative positions creating the need for strategic design considerations and interventions in anticipation of foreclosure.

Moreover, having gained a deeper comprehension of how white teachers employ distinctive and subversive strategies rooted in white ignorance, saviorism, innocence, and arrogance, functioning as both embodiments and enactments of resistance, I recognize the need to incorporate this insight into the professional development content. It is evident that these tendencies act as formidable barriers impeding progress along the trajectories of (un)learning. In future work, I recommend seamlessly integrating discussions on these specific barriers, treating them not only as subjects, and units of analysis but also as focal points for intervention within the arc of antiracist and anticolonial (un)learning.

Principle: The Rogue Settler Diligence Teacher Learning Pathway

Teachers who routinely engaged in critical reflection as they made sense of social justice phenomena and issues related to science and engineering were prepared to then engage in situated actions in their teaching which were anti-racist and anti-colonial. These teachers engaged in rogue settler diligence engaged in coordinations of settler malleability, settler responsibility, and settler rigor.

The preceding principle is deeply grounded in Donna Haraway's assertion that "it matters what matters we use to think other matters with" (2016, p. 12)—so does it matter, how matter comes to matter, particularly when engaged in *rogue method-making* (McKittrick, 2021). As previously discussed, merely accepting evidence of sensemaking is insufficient to demonstrate (un)learning, let alone transformation. This holds especially true when designing (un)learning environments that center critical content with the explicit goal of fostering rogue outcomes, such as antiracist and anticolonial science education in formal elementary school classrooms. Designing for critical

learning, calls for sensemaking that extends beyond epistemic engagement; it necessitates onto-axio-epistemic transformation to more effectively ensure the evolution of curricular and instructional methodologies and personal growth.

Such a premise reshapes the parameters of research and (un)learning, intensifying the criteria, particularly for white settler participants. It demands more than correct answers; it requires an exploration of the meaning of those answers in relation to one's positionality, the socio-ecological realities of society, implications within the educational context, science, teaching, and future implications, coupled with the practical application of (un)learning. Therefore, to achieve this, one must delve into deep sensemaking, critical meaning, and situated actions that demand "ganas," as my mother would say—an unwavering desire or willpower to effect change. For settler teachers, it entails being change-makers even when change is not obligatory, inviting attention in ways not commonly experienced by white individuals but familiar to Black, Brown, and Indigenous people as intrinsic to their acts of existence and survival, or in actively engaging in efforts to desettle and dismantle systems of oppression. What this entails for settler learners is not merely progressing towards becoming and practicing antiracist and anticolonial principles but remaining steadfastly involved in critical meaning-making and situated actions that necessitate the coordination and flexibility of settler responsibility, settler malleability, and settler rigor. And for critical learning design and designers it is both the objective and desired outcome.

Student Learning and Engagement in Just Worlding

This dissertation documents the socio-ecological and scientific brilliance of elementary school students as they learn about justice issues and engage in the creation of a more just world through science and engineering instruction. In Paper 2, Chapter 3, the research focuses on the

liberatory pedagogical commitments necessary to transform science teaching and learning. This transformation not only aims to exceed standard acquisition but also to open expansive student learning pathways grounded in consequential matters (Sanchez, 2023; Arada et al., 2023; Morales-Doyel, 2019) and transdisciplinary boundary crossing. The effectiveness of this approach is illustrated through a second-grade case study, which centers on an exemplary student's end-of-unit presentation. This case study highlights both the students' brilliance and the need for the cultivation and nurturing of students' relational epistemologies (Bang et al., 2018) to support their speculative (re)worlding in socio-ecologically precarious times. The focus on students' efforts to disrupt colonial logics and socio-ecological degradation within the classroom, curriculum, and science and engineering practices is expanded in Paper 3, Chapter 4. This paper follows third-grade students who prioritize multispecies justice, anti-racism, and anti-coloniality throughout a science unit. By honoring their speculative prowess, these students develop just worlding engineering design principles, offering renewed pathways towards critical relationality and radically caring futurities. This dissertation ultimately underscores the genius of young learners as visionaries for a more equitable and sustainable world through innovative educational practices.

Principle: Honoring kindred relationality as design priority

Relationality matters, and for children, having yet to become fully indoctrinated into nature/culture logics of division and competition with one another, relationality is both lens and language for onto-epistemological knowing and understanding. By honoring the sacredness of relationality, prioritizing it as a design priority for learning and instruction, science and

engineering become endeavors for radically caring ways forward towards collective well-being, as guided by children.

This principle of "Honoring kindred relationality as a design priority" underscores the significance of recognizing and prioritizing the inherent interconnectedness that exists within the learning environment, particularly for children who have not yet been deeply steeped in the divisive and competitive nature/culture logics of colonialism and capitalism. Relationality, understood as both a kincentric lens and life language, serves as a foundational for onto-epistemological knowing and understanding, often piecemealed as payment for entry to adulthood in dominant culture. This principle acknowledges that, for children, the interconnectedness of relationships is fundamental to their perception of the world and their place within it as Earth guardians of LandAirWaterStars and multispecies stakeholders as kin. By valuing and prioritizing the sacredness of relationality in the design of curriculum and instruction, the fields of science and engineering cease to be mere academic pursuits of reckless invention and transform into pathways for cultivating radically caring approaches of advocacy and restoration. This transformative perspective is guided by the intuitive and cultivated understanding of children, emphasizing collective well-being as a central goal.

By prioritizing relationality, science education becomes a shared journey, allowing students to explore and understand scientific concepts through collective engagement in eco-relational matters of consequence (Bang & Marin, 2015). This principle implies a shift towards pedagogical approaches that align with the inherent, complex caring nature of children, fostering a sense of responsibility towards providing a more holistic understanding of science and engineering within the consequential geographies across local and global relevant contexts. Science instruction becomes an avenue for cultivating not only cognitive understanding but also

emotional and ethical connections with the matter and *mattering* of those deserving to be remembered and re-membered into the contextualized learning. Teachers are encouraged to design learning experiences that evolve beyond individual achievement, position students to engage in collaboration as a process of learning how to be and become a responsible person within close networks within social, temporal and spatial networks (Elliot & Mexi, in press). Moreover, by honoring kindred relationality, science education becomes a dynamic process that actively involves students in shaping the learning journey, fostering a sense of agency and ownership (Arada, et.al., 2023). This principle encourages a departure from traditional or renovated banking information for Master-y teaching models, inviting educators to co-create learning environments that resonate with the relational competencies of children and provide a foundation for a more harmonious and interconnected society, none too soon.

Principle: Critical liberatory presencing of multispecies, LandAirWaterStars and rights of nature

Young people bring perspectives and ethical commitments for ecological and multispecies justice that should be leveraged in design activities in order to disrupt white human supremacy and to promote interdependent thriving of the living world. This requires critical and liberatory presencing of all living things in learning experiences.

Embracing the critical and liberatory presencing of multispecies and LandAirWaterStars entities, encourages educators to cultivate a curriculum that not only reflects diverse ecological perspectives but actively disrupts normative binary narratives of living and non-living and hierarchical paradigms of human supremacy. Through critical perspective-honoring pedagogies such as stakeholder and speculative visioning and design activities teachers counter systems of

dominance to foster an inclusive and just understanding of the interconnectedness of all Earthly beings. Furthermore by designing teaching, instruction and curriculum that prioritizes the critical and liberatory presence of LandAirWaterStars and multispecies kin that have been erased or marginalized through neoliberal, zero-point epistemological, consequentially neutral approaches and content, education moves towards authentic approaches of centering Indigenous science expertise, rather than tokenized tales abstractly connected to learning.

Principle: Transparency and humility as a valued design stance

Core embodiments and enactments of colonialism, coloniality and white supremacy are white arrogance in how it perceives knowledge and LandAirWaterStars as white property to do with as colonial and capitalism agendas demand, leveraging white innocence and ignorance to avoid accountability or awareness of impact. In contrast, childrens' eco-relational moral compasses lean towards honesty, disclosure, and inclusion derived from ethically curious humility; wondering and caring about what other beings' experiences and ideas are to best inform designs, actions and ways of thinking.

This principle introduces a fundamental shift in how science is both conducted and taught. This principle challenges the deeply ingrained colonial, coloniality, and white supremacist perspectives that have historically characterized the embodiment of knowledge and the treatment of the environment (LandAirWaterStars) as objectified possessions subjected to colonial and capitalist extractivist agendas. White arrogance, as a manifestation of these ideologies, perceives knowledge and the natural world as white property, leading to exploitative practices and a lack of moral accountability.

Moreover, this principle challenges the traditional power dynamics in scientific endeavors by urging scientists and engineers to approach their work, and for the fields to be considered as needing humility, acknowledging that other perspectives, values, priorities and thriving over colonial eco-logics of progress—such as high-speed trains, levies, extraction of Sand and Salmon and manipulation of storms through the exacerbation of climate change. This shift calls for a reevaluation of the power dynamics inherent in scientific research and pursuits, pushing against the arrogance that has historically perceived the natural world as a resource to be exploited without accountability.

For educators, rather than perpetuating a top-down dissemination of socio-ecologically inconsequential knowledge, for standards-assessment sake, educators would be encouraged to adopt a stance of transparency, openly sharing the process and purpose of scientific inquiry within real-world contexts and acknowledging the complexities and uncertainties inherent within the entanglements of society, Nature, science and engineering. From a stance of transparency and humility, scientists and engineers adopt orientations of empathetic obligation and educators can improve instruction by valuing the ethical curiosity and moral compasses of children. Teaching science through the lens of humility and transparency advocates for more than hands-on, settled experiments, calling for honest critical investigations designed to support childrens' grappling and navigation of on-going and escalating socio-ecological challenges, involves fostering a genuine interest in the experiences and ideas of other beings, incorporating diverse perspectives into the scientific discourse. This approach promotes a more inclusive and collaborative scientific community in service to the care of past, present and futures of Earthly beings and entities as essential kin.

Principle: Resistance and refusal as valued design practice

Far too often, due to racism, settler colonialism and coloniality, STEM endeavors have been perceived as worthy and inherently beneficial advancements without consideration of past and on-going atrocities, long-term implications, and paid costs of innovation with the lives, cultural ways of knowing and being, and sacredness of LandAirWaterStars and multispecies kin. Children guided and galvanized by their pre-colonial minds and critical awareness of the precarity of their world within worlds, move swiftly, and rightfully so, towards stances of resistance and refusal as they take up their eco-relational protector identities (Bell & Price, 2023) and lenses when considering engineering designs, scientific data and proposals for innovation. In other words, children better understanding the vulnerability of the Earth and Othered-kin are justifiable quick to say, how about no, to actions that cause harm, regardless of capitalistic gains. Educators honoring the resistance and refusals of children to ongoing oppressive formations help cultivate liberatory learning environments that can design more thriving futures.

This principle fosters a paradigmatic shift not only in STEM education but also within the broader domain of science, technology, and engineering. It advocates for a critical and reflective approach that acknowledges the historical and ongoing impacts of STEM endeavors, which have often been complicit in perpetuating social injustices and environmental degradation. By foregrounding the ethical and cultural dimensions of innovation, the principle disrupts the prevailing narrative that prioritizes technological advancement at the expense of human lives, cultural integrity, and ecological well-being. Children, by design of socially focused science learning are intently positioned to engage their pre-colonial perspectives and a keen awareness of their world's fragility, emerge as key actors in this transformation, swiftly embracing roles as eco-relational protectors. Their principled resistance and refusal to endorse actions causing harm,

irrespective of potential economic gains, exemplify a newfound consciousness that challenges the traditionally narrow focus of STEM education. This paradigm shift necessitates a reevaluation of pedagogical approaches, curriculum design, and institutional practices to align with ethical, cultural, and eco-relational considerations. In essence, the principle engenders a more responsible, ethical, and culturally inclusive foundation for STEM education and the broader realms of science, technology, and engineering, cultivating a generation of practitioners who prioritize societal and ecological well-being over unchecked technological progress.

Final Thoughts

The prospect of sustainability and, more ambitiously, thriving, is contingent upon more than the mere continuation of current educational trajectories, especially within the realms of science, engineering, and teacher education. As interconnected beings sharing the Earth as global kin, the planet must not be taken for granted or subjected to abuse. Acknowledging that generations of youth are presently and will continue to occupy classrooms underscores a fundamental reality that carries profound possibilities and responsibilities. This dissertation research not only illuminates the intricate eco-relational brilliance and radical care exhibited by some of our youngest geologists, engineers, scientists, and critically conscious citizens but also unveils novel trajectories for teacher (un)learning and pedagogical commitments. Drawing from the insights of the research participants, this work serves as an offering and an encouragement to embrace boldness, bravery, and a committed rogue approach against racism and coloniality in education. The work directly informs how district-level initiatives can be designed and implemented in ways to help shift educational practice and infrastructures focused on critical speculative design that supports more liberatory and thriving futures (Arada et.al. 2023; Bell, 2019). In echoing the

voices of the children, this dissertation affirms our profound capability and underscores the matter-of-fact reality that the future of our world depends profoundly on our collective actions.

References

Arada, K., Sanchez, A., & Bell, P. (2023). Youth as pattern makers for racial justice: How speculative design pedagogy in science can promote restorative futures through radical care practices. *Journal of the Learning Sciences*, 32(1), 76–109.

<https://doi.org/10.1080/10508406.2022.2154158>

Bang, M., & Marin, A. (2015). Nature–culture constructs in science learning: Human/non-human agency and intentionality. *Journal of Research in Science Teaching*, 52(4), 530-544.

Bang, M., Marin, A., & Medin, D. (2018). If Indigenous peoples stand with the sciences, will scientists stand with us?. *Daedalus*, 147(2), 148-159.

Bell, D. (1991). Racial realism. *Conn. L. Rev.*, 24, 363.

Bell, P. & Price, N. (2023, April 20). Restorying Nature-Culture Relations Towards Multispecies Ecological Caring Across Scales of Implementation. Presentation in symposium “Promoting Socio-ecological Caring Practices in Science Education: Models, Possibilities, and Complexities”

Bhaskar, R. (2008). *Dialectic: The pulse of freedom*. Routledge.

Bell, P. (2019). Infrastructuring teacher learning about equitable science instruction. *Journal of Science Teacher Education*, 30(7), 681-690.

Bell, P. (2004). On the Theoretical Breadth of Design-Based Research in Education. *Educational Psychologist*, 39(4), 243–253. https://doi.org/10.1207/s15326985ep3904_6

Design-Based Research (DBR) Collective. 2003. “Design-Based Research: An Emerging Paradigm for Educational Inquiry.” *Educational Researcher*, 32, no. 1: 5– 8.

Morales-Doyle, D. (2019). There is no equity in a vacuum: On the importance of historical, political, and moral considerations in science education. *Cultural Studies of Science Education*, 14, 485-491.

Elliott-Groves, E., & Meixi (2022). Why and how communities Learn by Observing and Pitching In: Indigenous axiologies and ethical commitments in LOPI (Cómo y por qué las comunidades Aprenden por medio de Observar y Acomedirse axiologías indígenas y compromisos éticos en el modelo LOPI). *Infancia y Aprendizaje*, 45(3), 567-588.
<https://doi.org/10.1080/02103702.2022.2062916>

Fishman, B. J., Penuel, W. R., Allen, A. R., Cheng, B. H., & Sabelli, N. O. R. A. (2013). Design-based implementation research: An emerging model for transforming the relationship of research and practice. *Teachers College Record*, 115(14), 136-156

Haraway, D. J. (2016). *Staying with the trouble: Making kin in the Chthulucene*. Duke University Press.

McKinney de Royston, M., & Sengupta-Irving, T. (2019). Another step forward: Engaging the political in learning. *Cognition and Instruction*, 37(3), 277-284.

McKittrick, K. (2020). Dear science and other stories. In *Dear science and other stories*. Duke University Press.

UN. (2015). Transforming our world: the 2030 Agenda for Sustainable Development.

Retrieved from: <https://sdgs.un.org/2030agenda>

Sanchez, A. (2023). The Social Focus Framework: Antiracist and Anticolonial Conscientization, Consequence, and Presencing in Science Education. In *Reimagining Science Education in the Anthropocene, Volume 2* (pp. 121-142). Cham: Springer International Publishing.

Smithsonian Institution Science Education Center (2023). Educating for Sustainable

Development-Perspectives of U.S. and Global Educators. Retrieved from:

https://ssec.si.edu/sites/default/files/SSEC_Educating_for_Sustainable_Development.pdf

Warren, B., Vossoughi, S., Rosebery, A. S., Bang, M., & Taylor, E. V. (2020). Multiple ways of knowing*: Re-imagining disciplinary learning. In *Handbook of the cultural foundations of learning* (pp. 277-294). Routledge.

Whelan, J. (2019). How does critical realism relate to critical theory?. *Social Theory Applied*.

Zucker, A., & Noyce, P. (2020). Lessons from the pandemic about science education. *Phi Delta Kappan*, 102(2), 44-49.

Appendix A:

Figure A1: The Anti-racist and Anti-colonial Social Focus Framework

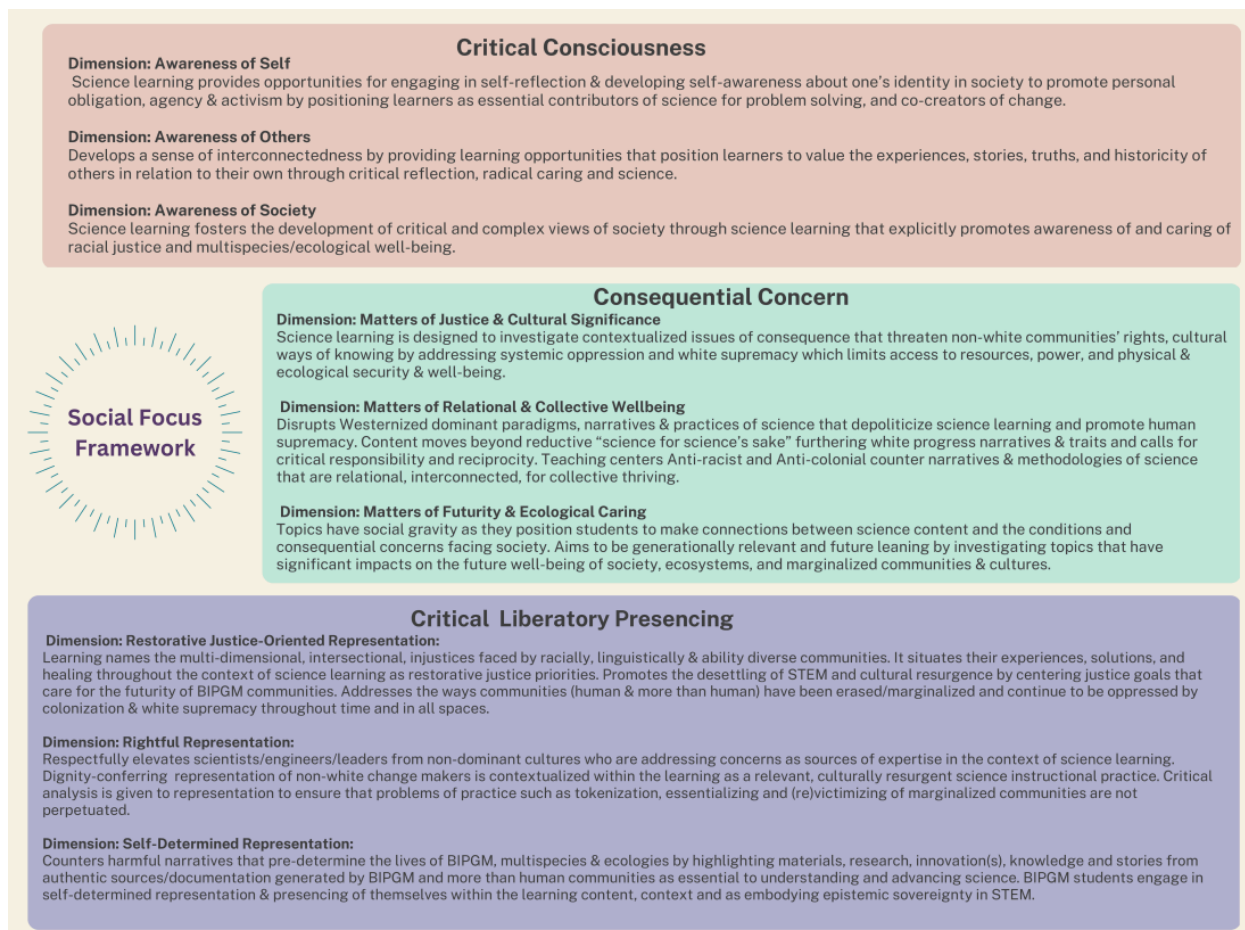


Figure A2: The Spectrum of Representation

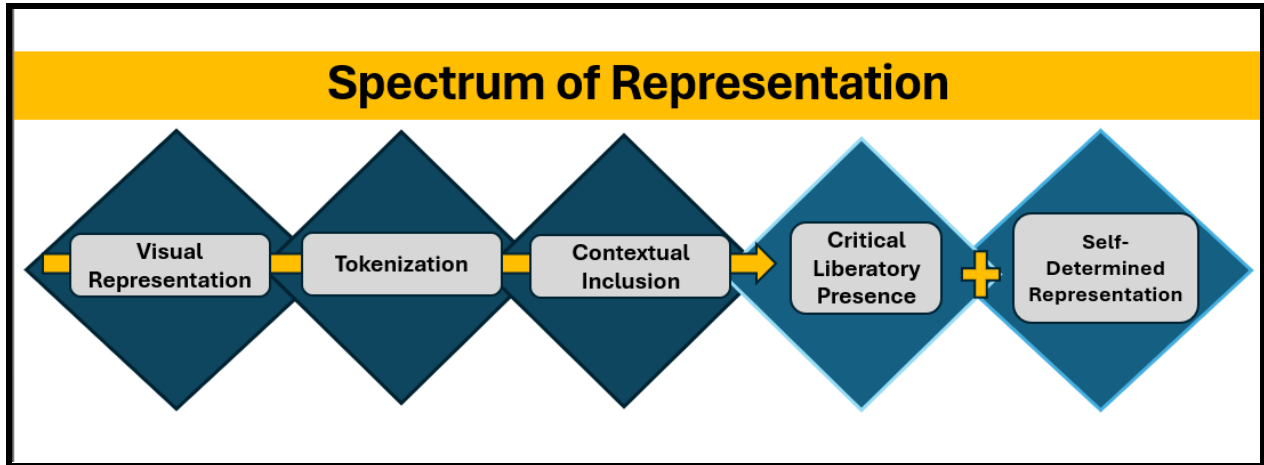


Figure A3: Critical Liberatory Presencing dimensions framework visual

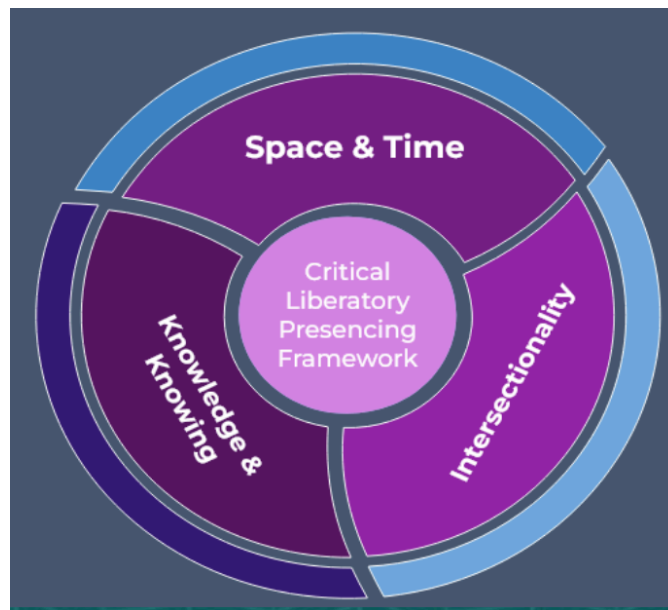


Figure A4: The Social Focus Iterative Unit Design Process

Social Focus Iterative Unit Design Process

6. Develop Unit Component Materials

Develop & prepare SF instructional lessons & materials (SFQs discourse, stakeholders, critical investigations, touchstone, & culminating lessons). Use SF framework to ensure materials attend to expansive, Antiracist & Anticolonial learning. Identify placement of models & summary charts

5. Braiding the Storyline

Using the unit map you created you will map your unit, braid in SF instructional lessons beginning with the SF question then weave additional lessons throughout the storyline of unit. The unit should progressively build toward meaningful critical investigations & meaningful culminating lessons.

4. The Social Focus Question/Phenomenon Question(s)

Depending on your approach you will develop a unit SF question that parallels the curriculum phenomenon or the SF question will be the unit question if it is replacing the curriculum phenomenon. *Question is critically expansive to embrace complexity of thought & application of learning, not merely for assessment. Then craft progressive chapter questions.*

1. Mapping the Unit: Noticing & Interpreting

This step requires you to map out the lessons to identify the progression of learning, standards & inventory available/missing materials & learning. build. This step is essential for critical noticing, interpreting & identifying dominant-colonial narratives, reductive & inconsequential learning.

2. Consequential Concern Brainstorm

Collaboratively brainstorm generational, meaningful justice topics of socio-ecological gravity connected to the unit content & phenomenon. Vet topic using the Consequential Concern dimension of SF framework.

3. Designing for Critical Liberatory Presenting

Using the critical & liberatory dimension of the SF framework identify & research ways to presence unrepresented communities throughout the unit as related to the unit's consequential concern(s). Ensure presenting of knowledge(s), concerns considers past-future facing time & space, & intersectionality

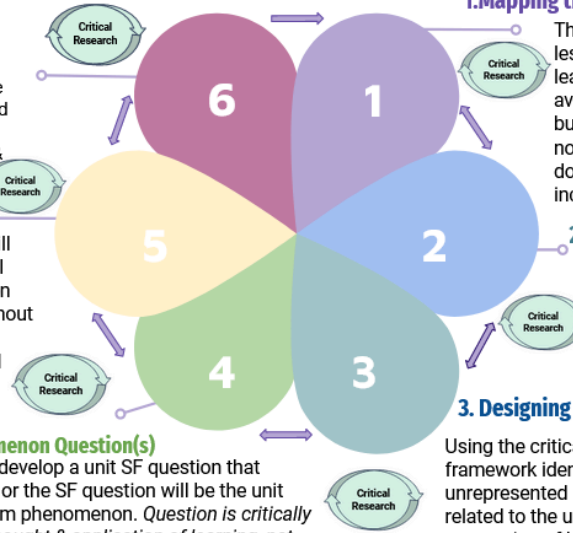
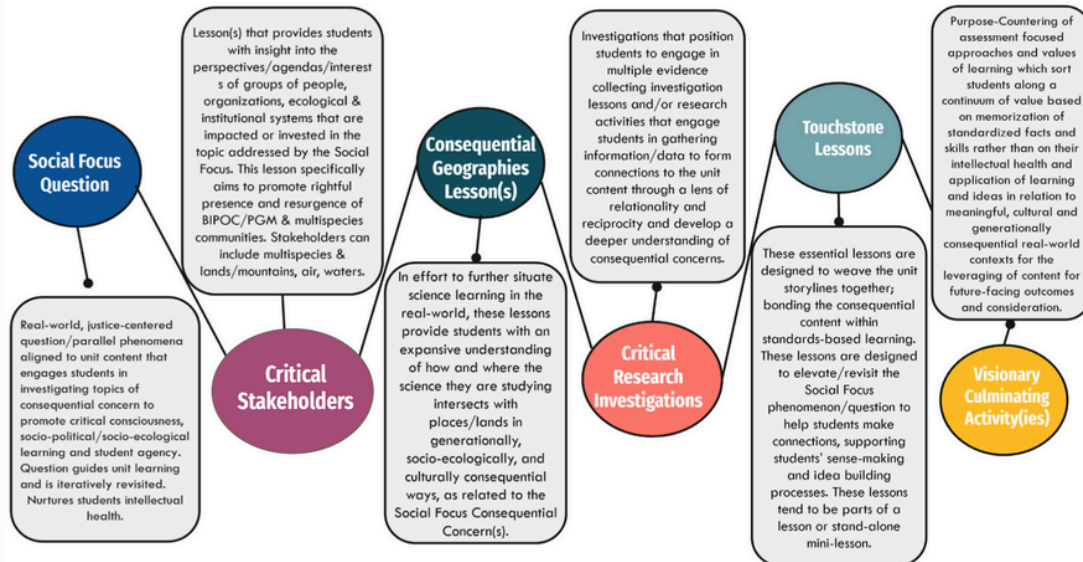


Figure A5: Social Focus Pedagogical Commitments

Social Focus Pedagogical Commitments



Appendix B:

Figure B1: Stakeholders Final Assignment

Final Assignment: Stakeholders Design Meeting Invitation

Jan. 25th/26th Science - Invitations to the Design Meeting
In this activity you will write an invitation to a stakeholder in the Kuala Lumpur-Singapore train project (train article #2) to a design meeting.

1. On the first page add **T** to say who you are inviting to the design meeting (which stakeholder?).
2. On the next page, add **T** **q** **f** to create a letter (or a card) inviting that stakeholder to come to the design meeting. Use the tables on pg. 3 & 4 to help you (they are the notes from our class meetings).
3. Be sure to include in your invitation:
 - An explanation of why they are being invited and a little about the train.
 - Why it is important that they come.
 - What unique perspective you hope they share.
 - At least 2 questions you want them to answer.
4. Don't be afraid to get creative with who your stakeholders are (people, animals, or even nature all count) and how you invite them!
5. Extra Credit: On page 5 tell about any design improvements for this train that would benefit the stakeholder you invited.

Assignment Page 1

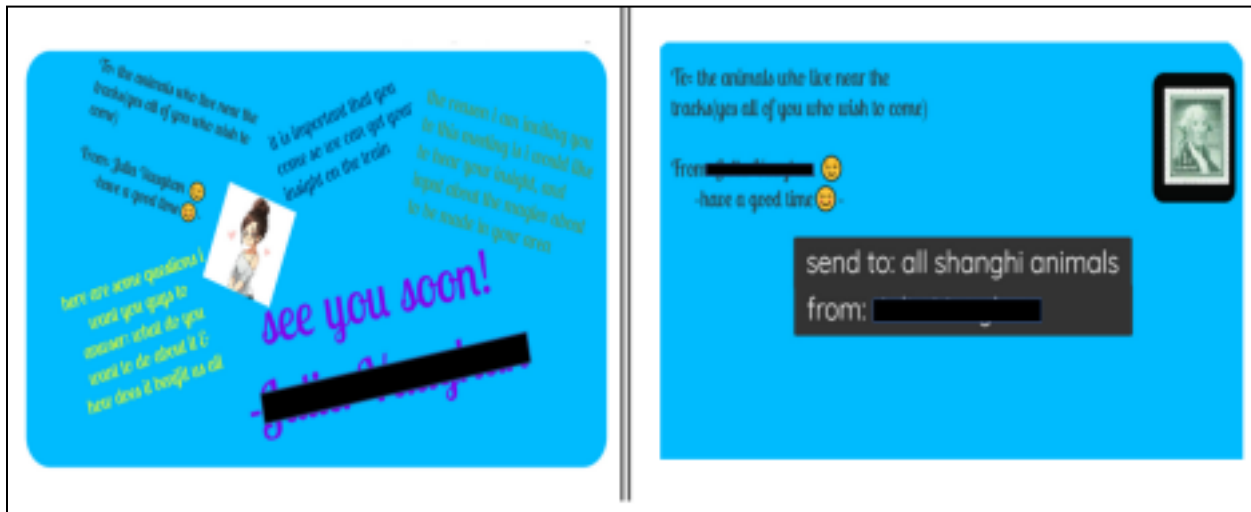
Invitation
Who is your invitation going to? (the stakeholder)

To:
From:

Assignment Page 2

Write your invitation below. You can include text, shapes, and images.

Figure B2: Example of digital format for students stakeholder invitations



To all animals who live near the tracks (yes all of you who wish to come), the reason I am inviting you to this meeting is I would like to hear your insight, and input about the maglev train about to be made in your area, it is important that you come so we can get your insight on the train, here are some questions
 i want you guys to answer: what do you want to do about it & how does it benefit us all? See you soon have a good time 😊
 send to: all shanghai animals
 from: